

DOCUMENT RESUME

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TITLE Refrigeration and Cryogenics Specialist.
J3ABR54530

INSTITUTION Air Force Training Command, Sheppard AFB, Tex.

PUB DATE 83

NOTE 679p.; The package includes new and replacement pages as of February, 1984.

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DESCRIPTORS *Air Conditioning; *Air Conditioning Equipment; Course Content; Electricity; *Job Skills; Lesson Plans; Military Personnel; *Military Training; Occupational Safety and Health; Postsecondary Education; *Refrigeration; *Refrigeration Mechanics; Skilled Occupations; Units of Study

IDENTIFIERS Air Force; Military Curriculum Materials

ABSTRACT

This document package contains an Air Force course used to train refrigeration and cryogenics specialists. The course is organized in six blocks designed for group instruction. The blocks cover the following topics: electrical principles; fundamentals of tubing and piping; metering devices, motor controls, domestic and commercial refrigeration; fundamentals of air conditioning; air conditioning controls; and commercial air conditioning. The following materials are included in the package: plan of instruction (lesson plans) for the teacher (including outline of course content, time, support materials and guidance, training equipment, training methods, and instructional guidance); study guides/workbook for each major topic block (containing objectives, information, and exercises for each lesson), and workbooks containing review tests for each subject block. Materials are illustrated with line drawings. (KC)

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ED 273751

REFRIGERATION AND CRYOGENICS
SPECIALIST

J3ABR54530

SHEPPARD
TECHNICAL TRAINING CENTER

UNITED STATES AIR FORCE

U.S. DEPARTMENT OF EDUCATION
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OE 044 873

PLAN OF INSTRUCTION
(Technical Training)

REFRIGERATION AND CRYOGENICS SPECIALIST



SHEPPARD TECHNICAL TRAINING CENTER

20 September 1982-Effective 3 November 1982 with Class 821103

Changed 8 June 1983-Effective 21 July 1983 with Class 830721

Changed 10 February 1984-Effective 28 February 1984 with Class 840228

LIST OF CURRENT PAGES

This POI consists of 79 current pages issued as follows:

<u>Page No.</u>	<u>Issue</u>
*Title	10 Feb 84
*A	10 Feb 84
1	Original
ii.	Original
*iii	10 Feb 84
1 thru 9.	Original
10.	Blank
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40.	Blank
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83.	Original

CHANGE NOTICE INSTRUCTIONS

Effective 28 February 1984. POI J3ABR54530 001, 20 September 1982, is changed as follows:

1. Make write-in changes identified on page iii.
2. Remove replaced or deleted pages and insert changed and new pages according to the above listing.
3. The asterisk (*) above indicates that the page is a replacement or addition or has been deleted by this change notice.



DAVID R. JACKSON, Colonel, USAF
Commander, 3770 Technical Training Group

DISTRIBUTION: ATC/TTQJ-1; AU/LSE-1; CCAF-AY-1; USAFOMC/OMY-1;
Sheppard: XPMT-1; TTGIM-50; TTGXD-2; TTGXR-1; TTS-1.

Changed 10 February 1984.

DEPARTMENT OF THE AIR FORCE
USAF Technical Training School (ATC)
Sheppard Air Force Base, Texas 76311

PLAN OF INSTRUCTION J3ABR54530 001
(PDS Code YSX)
20 September 1982

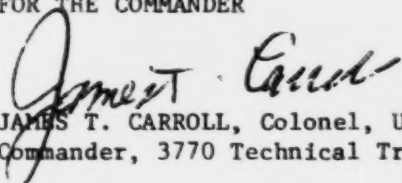
FOREWORD

1. PURPOSE. This publication is the plan of instruction (POI) when the pages listed on Page A are bound into a single volume. The POI contains the qualitative requirements for course J3ABR54530 001, Refrigeration and Cryogenics Specialist, in terms of criterion objectives for each unit of instruction and shows time, training standard correlation, and support materials and guidance. When separated into units of instruction, it becomes the lesson plan/Part I. This POI was developed according to AFR 50-8, Instructional Systems Development (ISD), and ATCR 52-6, Curricula Documentation.

2. COURSE DESIGN/DESCRIPTION. The instructional design for this course is Group/Lock Step. The course trains airmen to perform duties prescribed in AFM 39-1 for Refrigeration and Cryogenics Specialists, AFSC 54530. Training includes the use of publications and forms; and identification, location, function, installation, operational checking, servicing, repair and maintenance of refrigeration and air conditioning systems. The course also includes water analysis and conditioning. In addition, military training is provided on driver education, troop information program, commander's calls/briefings, etc.

3. REFERENCES. This POI is based on Specialty Training Standard, 54530/50/70, July 1980, and Course Chart J3ABR54530 001, 11 August 1982.

FOR THE COMMANDER


JAMES T. CARROLL, Colonel, USAF
Commander, 3770 Technical Training Group

Supersedes Plan of Instruction J3ABR54530 001, 22 December 1980
OPR: 3770 Technical Training Group
DISTRIBUTION: Listed on Page A

WRITE-IN CHANGES

Effective Date: 21 July 1983

<u>BLOCK</u>	<u>PAGE</u>	<u>ACTION</u>
I	12	Criterion objective I6f: Underline "8g(8)"
II	44	Criterion objective III8h: Underline "16c"
All	5 thru 79	Student Instructional Material: After each Sw title, add, " (DS)"
All	3 thru 83	All criterion objectives: Delete "W" by lining through.

Write-In Changes

Effective Date: 28 February 1984

<u>Block</u>	<u>Page</u>	<u>Action</u>
I	1	Criterion objective I 1a(12): After energy, add "(Fraud, Waste and Abuse)"
IV	47	Criterion objective VI 1a: After 1a(3) add Teaching Step "(4) Engineered Performance Standards)"
IV	47	Under <u>Student Instructional Materials</u> , add "DS AFS 54, 55 and 56, Engineered Performance Standards"

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Electrical				
1. COURSE CONTENT				2. TIME
1. Orientation a. Course introduction to include: (1) Welcome (2) Overview of course content, its goals and administration (3) Responsibilities of students (4) Relationship of graduate's performance to Air Force mission (5) Benefits of the CCAF and its assignment of academic credit for training completed at regional accredited institutions (6) Types and uses of instructional material (7) Student progress policies to include: (a) Progress checks (b) Written tests (c) Special individual assistance (d) Proficiency advancement (e) School grading (8) Student recognition program (9) Effective study techniques (10) Procedures for shelter exercises and fire evacuation plan (11) Student critique program and its objective (12) Conservation of training materials, resources and energy (Fraud, Waste and Abuse) (13) Disposition of eliminees				2/0
SUPERVISOR APPROVAL OF LESSON PLAN				
SIGNATURE AND DATE		SIGNATURE AND DATE		
POI NUMBER J3ABR54530 001		BLOCK I	UNIT 1	DATE 20 Sep 1982
				PAGE NO. 1

COURSE CONTENT

(14) Necessity of TDY personnel clearing through In-Processing at Base Personnel

(15) Instructions for completion of STTC Form 120, Processing Checklist - TDY student personnel

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SG J3ABR54530 001-I-1, Orientation

ATCPT 52-11, Study Skills

Audiovisual Aids

Prenarrated Slide: NSS 55-42, Student Critique Program

Prenarrated Slide: Community College of the Air Force

Prenarrated Slide: NSS 60-67, Generality Gap

Chart Set, Chain of Command

Training Methods

Lecture/Discussion (2 hrs)

Instructional Guidance

Welcome students to the course and discuss orientation items listed.

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Electrical				
1.	COURSE CONTENT			2. TIME
2.	Civil Engineering Organization and Safety			7/0.5
	a. Using the materials provided, identify the career ladder progression, three duties of the apprentice refrigeration/cryogenics specialist, mission, and organization of CE units, with no more than four errors. STS: <u>1a, 1b, 1c</u> Meas: ~~W~~ , PC			(1.5/0)
	(1) Civil Engineering Mission and Organization (2) Mechanical/electrical career field (3) Progression career ladder (4) Duties of the AFSCs skill level			
	b. Using material provided, identify basic facts relating to the AF Occupational Safety and Health (AFOSH) program with 80% accuracy. STS: <u>3a, 3b, 3e, 3f, 3g</u> Meas: ~~W~~ , PC			(1.5/0)
	(1) AFOSH Standards for AFSC 545X0 (2) Hazards of AFSC 545X0 (3) Job safety, fire prevention and occupational health training (4) Hazard reporting and abatement (5) Mishap reporting and investigation			
	c. Using material provided, state three of the rules concerning individual responsibilities to the AFOSH program. STS: <u>3d</u> Meas: ~~W~~ , PC			(1.5/0)
	(1) Individual responsibilities			
	d. Given the information, list the first aid procedures for electrical shock, controlling bleeding, traumatic shock, and heat exhaustion and heat stroke, with 80% accuracy. STS: <u>3i(1), 3i(2), 3i(3), 3i(4)</u> Meas: ~~W~~ , PC			(2.5/.5)
	(1) Electrical shock (2) Controlling bleeding (3) Traumatic shock (4) Heat exhaustion and heat stroke			
SUPERVISOR APPROVAL OF LESSON PLAN				
SIGNATURE AND DATE		SIGNATURE AND DATE		
POI NUMBER J3ABR54530 001		BLOCK I	UNIT 2	DATE 20 Sep 1982
				PAGE NO. 3

COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SG AFS 54, 55, and 56, All Courses - Safety

SW J3ABR54530 001-I-2, Civil Engineering Organization and Safety

WB J3ABR54530 001-I-2, Civil Engineering Organization and Safety

2TPT-9039-01, Civil Engineering Mechanical/Electrical Career Field

Training Methods

Lecture/Discussion (7 hrs)

Directed Study (0.5 hr)

Instructional Guidance

Discuss how the refrigeration and cryogenics specialist career field is related to the mission and organization of civil engineering units. Show the student where he will fit into this organization. Review the procedures given in SG AFS 54, 55, and 56 for ground accident reporting and first aid for electrical shock and other emergencies. Evaluate objectives by using ATC Form 98. Directed study assignments will be accomplished by a written directed study examination.

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Electrical				
1.		COURSE CONTENT		2. TIME
3. Hand Tools		a. Given randomly selected hand tools, identify them, state their use, safety precautions and maintenance requirements, with 75% accuracy. STS: 3h(6), 7a Meas: ~~W~~ , PC (1) Types of hand tools and their application (2) Care of hand tools (3) Safety precautions when using tools b. Select a drill bit, and drill one hole in the metal provided, using a drill press. Lubricate the equipment as necessary and observe electrical/mechanical safety precautions. The hole must be within 1/8" of the point designated by the instructor. Instructor assistance is permitted. STS: 3h(1), 3h(2), 7b Meas: ~~W~~ , PC (1) Use and maintenance of shop equipment (2) Safety precautions when using shop equipment		2/0 (1/0) (1/0)
SUPPORT MATERIALS AND GUIDANCE				
<u>Student Instructional Materials</u> SW J3ABR54530 001-I-3, Hand Tools(DS) WB J3ABR54530 001-I-3, Hand Tools 2TPT-3200-01, Common Hand Tools Commercial Text, Modern Refrigeration and Air Conditioning				
<u>Training Equipment</u> Hand Tools Drill Press				
<u>Training Methods</u> Lecture/Discussion (1.25 hrs) Demonstration (0.25 hr) Performance (0.5 hr)				
SUPERVISOR APPROVAL OF LESSON PLAN				
SIGNATURE AND DATE		SIGNATURE AND DATE		
POI NUMBER		BLOCK		PAGE NO.
J3ABR54530 001		I		5
UNIT		DATE		
3		20 Sep 1982		

COURSE CONTENT

Instructional Guidance

Place adequate emphasis on the use of the drill press. Students should always wear goggles when operating the drill press. Criterion objective performance may be practiced before the performance measurement activity begins. Instructor assistance may be given during the performance of criterion objective 3b. Evaluate criterion objectives by using ATC Form 98.

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Electrical				
1. COURSE CONTENT				2. TIME
4. Electrical Principles and Circuits				17.5/6.5
a. Given a series of incomplete statements pertaining to elemental electricity, current, resistance, voltage, and magnetism, explain the basic principle of each by completing 80% of the statements correctly. STS: <u>8b</u>, <u>8d</u>, <u>8e</u> Meas: ~~W~~, PC (1) Matter (2) Elements (3) Molecule (4) Atom (5) Electron (6) Coulomb (7) Ampere (8) Resistance (9) Voltage (10) Magnetism				(4/3)
b. Given ten military standard symbols, including those for switches, circuit breakers, solenoid valves, and fuses, identify each and state the types and purpose for eight of the ten components. STS: <u>8a</u>, <u>8f(2)(a)</u>, <u>8f(2)(b)</u>, <u>8f(2)(c)</u>, <u>8f(2)(d)</u> Meas: ~~W~~, PC (1) Circuit symbols (2) Switches (3) Circuit breakers (4) Fuses (5) Solenoid Valves				(3/.5)
SUPERVISOR APPROVAL OF LESSON PLAN				
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COURSE CONTENT

c. Given the material and information, draw a simple, series, and parallel circuit. State the current, voltage, and resistance relationship in each circuit, with a total of no more than two errors. (3/1)

STS: 8f(1)(a), 8f(1)(b), 8f(1)(c), 8f(3) Meas: ~~W~~, PC

- (1) Electrical symbols and diagrams
- (2) Simple circuits
- (3) Series circuits
- (4) Parallel circuits

d. Using an electrical trainer, construct an operative series and parallel circuit with instructor assistance. STS: 3h(1), 8f(5) Meas: ~~W~~, PC (3/0)

- (1) Series circuit construction
- (2) Parallel circuit construction
- (3) Safety precautions

e. Using an electrical meter provided, select the proper mode and determine the electrical values of a designated electrical circuit to + 5% of meter scale value. No more than one assist on safety. (4.5/2)

STS: 3h(1), 7c, 8h(1) Meas: ~~W~~, PC

- (1) Operating principles of electrical meters
- (2) Selection of meters
- (3) Use of meters to determine values
- (4) Care of meters
- (5) Safety precautions

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SW J3ABR54530 001-I-4, Electrical Principles and Circuits (DS)

WB J3ABR54530 001-I-4, Electrical Principles and Circuits
Commercial Text, Modern Refrigeration and Air Conditioning

COURSE CONTENT

Audiovisual Aids

Chart Set, Electrical Meters
Transparencies, Set, Electrical Principles
Training Film: 27874, Basic Electricity

Training Equipment

Trainer, Fundamental Electrical Principles
Trainer, Multimeter
Trainer, Electrical Circuits and Meter Readings

Training Methods

Lecture/Discussion (12 hrs)
Demonstration (2 hrs)
Performance (3 hrs)
Training Film (.5 hr)
Directed Study (6.5 hrs)

Instructional Guidance

Place adequate emphasis on safety precautions involved in use of electrical test equipment and on careful handling of delicate and expensive test equipment. Evaluate criterion objectives by using ATC Form 98. Criterion objective performance may be practiced before the performance measurement activity begins. Instructor assistance may be given on some criterion objectives. Directed study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.

5. Written Test and Test Critique

1.5

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Electrical				
1.	COURSE CONTENT			2. TIME
6. Wiring Systems, Motors, Motor Starters and Overloads				(16/4.5)
a. Given the information, state the purpose and function of two, three and four wire electrical systems with no more than three errors. STS: <u>8f(4)</u> Meas: ~~W~~ , PC				(3/.5)
(1) Two wire systems (2) Three wire systems (3) Four wire systems				
b. Given the information, state the general construction features of single and three phase motors with no more than two errors. STS: <u>8g(1)</u> Meas: ~~W~~ , PC				(3/.5)
(1) Single phase motors (2) Three phase motors				
c. Given the information, list the steps in installing and servicing electric motors with no more than two errors. STS: <u>8g(2)</u> , <u>8g(6)</u> Meas: ~~W~~ , PC				(2/.5)
(1) Electric motor installation (2) Electric motor servicing				
d. Using a motor trainer and a multimeter, determine the start and run windings of an electric motor, connect the motor and reverse its rotation with instructor assistance. STS: <u>8g(3)</u> , <u>8g(4)</u> , <u>8g(5)</u> Meas: ~~W~~ , PC				(4/1.5)
(1) Electric motor windings (2) Connection (3) Reversing rotation				
e. Using an electrical trainer, service the motor starters with instructor assistance. STS: <u>8g(7)</u> Meas: ~~W~~ , PC				(2/1)
(1) Types of motor starters				
SUPERVISOR APPROVAL OF LESSON PLAN				
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COURSE CONTENT

(2) Servicing procedures

f. Given information, state the types and function of electrical overload protectors with no more than two errors. STS: 3g(8) (2/.5)
Meas: ~~W~~, PC

(1) Types of overload protectors

(2) Function of overload protectors

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SW J3ABR54530 001-I-6, Wiring Systems, Motors, Motor Starters and Overloads (DS)

WB J3ABR54530 001-I-6, Wiring Systems, Motors, Motor Starters and Overloads

Commercial Text, Modern Refrigeration and Air Conditioning

Audiovisual Aids

Charts, Set, Alternating Current Generation

Transparencies, Set, Alternating Current Wiring Systems

Training Equipment

Trainer, Electric Motor and Three-Phase Wiring Operation

Trainer, Motor Starter

Trainer, Motor and Motor Starter

Multimeters

Training Methods

Lecture/Discussion (13.25 hrs)

Demonstration (.75 hr)

Performance (2 hrs)

Directed Study (4.5 hrs)

Instructional Guidance

Insure that the multimeters are used correctly and emphasize the following workbook procedures. Evaluate criterion objectives by using ATC Form 98. Criterion objectives performance may be practiced before the performance measurement activity begins, if time permits. Instructor assistance may be given on some criterion objectives. Directed study assignments will be accomplished outside the classroom and will be verified the following day by a written directed study examination.

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Electrical				
1.	COURSE CONTENT			2. TIME
7.	Schematic Interpretation and Electrical Troubleshooting			12.5/3.5
	a. Given a schematic diagram and an electrical trainer, trace the circuit designated by the instructor with no more than two errors. STS: <u>8f(6)</u> Meas: ~~W~~ , PC			(2/0.5)
	(1) Schematic interpretation			
	b. Using an electrical trainer, and a meter, safely locate five of six instructor induced malfunctions. STS: <u>3h(1)</u> , <u>8c</u> , <u>8h(2)</u> Meas: ~~W~~ , PC			(4/0.5)
	(1) Principles of troubleshooting (2) Application of electrical principles (3) Safety precautions			
	c. Working as a member of a team, using electrical test equipment and an electrical trainer, isolate three of six instructor induced malfunctions. STS: <u>8h(3)</u> Meas: ~~W~~ , PC			(2.5/1.5)
	(1) Isolation procedures			
	d. Given the information, state the basic steps for replacing defective electrical units and components with no more than two errors. STS: <u>8h(4)</u> Meas: ~~W~~ , PC			(1.5/.5)
	(1) Replacement procedures			
	e. Using an electrical trainer and given a minor electrical discrepancy, repair the circuit or unit with no more than one instructor assist. STS: <u>8h(5)</u> Meas: ~~W~~ , PC			(2.5/0.5)
	(1) Precautions (2) Procedures			
<u>Student Instructional Materials</u> SW J3ABR54530 001-I-7, Schematic Interpretation and Electrical Troubleshooting (DS) WB J3ABR54530 001-I-7, Schematic Interpretation and Electrical Troubleshooting <u>Commercial Text, Modern Refrigeration and Air Conditioning</u>				
SUPERVISOR APPROVAL OF LESSON PLAN				
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COURSE CONTENT

Audiovisual Aids

Charts, Set, Electrical Troubleshooting
Transparencies, Set, Electrical Troubleshooting

Training Equipment

Trainer, AC Troubleshooting
Multimeters

Training Methods

Lecture/Discussion (5 hrs)
Demonstration (3 hrs)
Performance (4.5 hrs)
Directed Study (3.5 hrs)

Instructional Guidance

Place adequate emphasis on safety precautions involved in the use of electrical test equipment. Criterion objective performance may be practiced before the performance measurement activity begins. Directed Study assignments will be accomplished outside the classroom, and will be verified the following day by a written Directed Study examination.

- | | |
|---|-----|
| 8. Written Test and Test Critique | 1.5 |
| 9. Physical Conditioning - Days 3, 5, 8, 10 | 4 |

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Fundamentals				
1.	COURSE CONTENT			2. TIME
1. Refrigeration Lines and Tubing Fabrication				
a. Given an assortment of copper tubing/pipe, identify the tubing/pipe by size and type with 80% accuracy. STS: 9a Meas: ~~W~~ , PC				6/1 (1/5)
(1) Types of tubing/pipe and their applications (2) Sizing tubing/pipe				
b. Given a ruler, tubing cutter, tubing bender, and a roll of copper tubing, measure, cut and bend tubing to an operational configuration, without personal injury or equipment damage. Finished tubing must conform to instructor's template $\pm 1/8"$. STS: <u>3h(6)</u> , 9b, 9c Meas: ~~W~~ , PC				(1.5/.5)
(1) Tools for measuring, cutting and bending (2) Procedures for cutting and bending copper tubing (a) Safety precautions (b) Cutting of copper tubing (c) Bending of copper tubing				
c. Given a ruler and an assortment of refrigeration fittings, identify one of each type by size and type, with no more than one error. STS: 9f Meas: ~~W~~ , PC				(1.5/0)
(1) Selection and identification of refrigeration fittings (2) Measurement of fittings				
d. With instructor assistance and using a ruler, tubing cutter, flaring kit and copper tubing, measure, cut, flare and swage tubing to a rough operational condition. Swage will be suitable for a solder connection. STS: 9b, 9d, <u>9e</u> Meas: ~~W~~ , P C				(2/0)
(1) Tools used for flaring and swaging (2) Flaring procedures (3) Swaging procedures				
SUPERVISOR APPROVAL OF LESSON PLAN				
SIGNATURE AND DATE		SIGNATURE AND DATE		
POI NUMBER J3ABR54530 001		BLOCK II	UNIT 1	DATE 20 Sep 1982
				PAGE NO. 15

COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SW J3ABR54530 001-II-1, Refrigeration Lines and Tubing Fabrication(DS)

WB J3ABR54530 001-II-1, Refrigeration Lines and Tubing Fabrication

Commercial Text, Modern Refrigeration and Air Conditioning

Training Equipment

Flaring Kits

Swaging Tools

Tubing Cutters

Tubing Benders

Trainer, Air Conditioning and Refrigeration Hardware

Trainer, Air Conditioning and Refrigeration Hardware Samples for Measuring

Training Methods

Lecture/Discussion (3 hrs)

Performance (3 hrs)

Directed Study (1 hr)

Instructional Guidance

Place adequate emphasis on safety precautions involved when working with tube fabrication and tools. Use minimum lengths of tubing and/or used tubing for flaring and swaging to conserve material. Have students practice flaring both 3/8" and 1/4" tubing (expertise needed for Day 16) and swage sufficient tubing to practice 2a, 2b, 2c, and 2d before performance is evaluated. Distribute tools and demonstrate 1b immediately prior to students' performance to insure higher percentage of success and conservation of materials. Directed study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Fundamentals				
1. COURSE CONTENT				2. TIME
2. Soldering and Brazing				8/2
a. With instructor assistance and using the hydrocarbon torch, soft solder a copper swage joint with at least 75% penetration, with no excess inside of joint, observing safety precautions for flammables. STS: 3h(4), <u>10a(1)</u> Meas: ~~W~~ , PC				(2/1)
(1) Hydrocarbon torch (2) Safety precautions for flammables (3) Soft solder				
b. With instructor assistance and using the hydrocarbon torch, hard solder a copper swage joint with at least 75% penetration, with no excess inside of joint. STS: <u>3h(4)</u> , <u>10a(2)</u> Meas: ~~W~~ , PC				(2/0)
(1) Hard solder (2) Safety precautions				
c. With instructor assistance and using the hydrocarbon torch and aluminum repair kit provided, make a simple repair to damaged aluminum tubing. The repair material must adhere to the aluminum and must be of the approximate color to indicate a leak proof repair. STS: <u>10a(3)</u> Meas: ~~W~~ , PC				(2/1)
(1) Aluminum repair (2) Precautions				
d. With instructor assistance and using the oxyacetylene torch, silver solder/braze a copper swage joint of each type, with at least 75% penetration with no excess inside the joint. STS: <u>10b</u> Meas: ~~W~~ , PC				(2/0)
(1) Oxyacetylene torch (2) Silver solder (3) Sil-foss Brazing				
SUPERVISOR APPROVAL OF LESSON PLAN				
SIGNATURE AND DATE		SIGNATURE AND DATE		
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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SW J3ABR54530 001-II-2, Soldering and Brazing (DS)

WB J3ABR54530 001-II-2, Soldering and Brazing

Commercial Text, Modern Refrigeration and Air Conditioning

Audiovisual Aids

Charts, Set, Oxygen and Acetylene

Training Equipment

Trainer, Welding Dual-Type

Soldering Equipment

Special Equipment: Plastic, Epoxy and Liquid Aluminum Repair Material

Training Methods

Lecture/Discussion (2 hrs)

Demonstration (2 hrs)

Performance (4 hrs)

Directed Study (2 hrs)

Instructional Guidance

Place emphasis on safety precautions involved in the use of torches, soldering equipment, acetylene cylinders and the handling of hot metal. To prevent excessive trips to lab area, teach all the supportive objectives prior to doing the projects. Provide assistance during performance of criterions as indicated on the ATC Form 98. Directed Study assignments will be accomplished outside of the classroom, and will be verified the following day by a written directed study examination.

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Fundamentals				
1.	COURSE CONTENT			2. TIME
3.	Principles of Physics			6/2
	a. Given a commercial text, complete the assigned factual statements involving the principles of physics with 80% accuracy. STS: <u>11a</u> , <u>11b</u> , <u>11c</u> , <u>11d</u> , <u>11e</u> , <u>11f</u> , <u>11g</u> , <u>11h</u> , <u>11i</u> , <u>11j</u> Meas: ~~W~~ , PC			(4/2)
	(1) Basic structure of matter (2) Thermodynamics (3) British Theraml Unit (BTU) (4) Heat flow and transfer (5) Specific, sensible and latent heat (6) Changes of state of matter (7) Pressure - vacuum (8) Laws of gases (9) Metric conversion			
	b. Given a PT chart, explain the pressure-temperature relationship for different refrigerants at various temperature/pressures with 80% accuracy. STS: <u>12a</u> , <u>12c</u> , <u>12d</u> Meas: ~~W~~ , PC			(2/0)
	(1) Definition and characteristics of refrigerants (2) Characteristics of Halo-Carbon refrigerants (3) Pressure-Temperature relationship chart			
SUPPORT MATERIALS AND GUIDANCE				
<u>Student Instructional Materials</u> SW J3ABR54530 001-II-3, Principles of Physics (DS) WB J3ABR54530 001-II-3, Principles of Physics Commercial Text, Modern Refrigeration and Air Conditioning				
SUPERVISOR APPROVAL OF LESSON PLAN				
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COURSE CONTENT

Audiovisual Aids

Charts, Set, Refrigeration System

Training Film: 27633, Refrigeration - Principles of Mechanical
Refrigeration Systems

Slide Set: ATS 54-18, Modified Principles of Refrigeration

Training Equipment

Trainer, Refrigeration Service Valve

Trainer, Manifold Gauge Assembly

Trainer, Pressure Gauge

Training Methods

Lecture/Discussion (2.5 hrs)

Demonstration (1 hr)

Performance (2 hrs)

Training Film (.5 hr)

Directed Study (2 hrs)

Instructional Guidance

Evaluate criterions by using the ATC Form 98. Directed Study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Fundamentals				
1.	COURSE CONTENT			2. TIME
4.	Refrigeration Components and Accessories			8.5/3
	a. Given a list of five principles, select the ones which define the operating principles of the compression refrigeration cycle. One error permitted. STS: <u>14a</u> Meas: ~~W~~ , PC			(.5/0)
	(1) Operating principles			
	b. Given the names of three refrigeration components, explain the basic types, purpose, and principle of operation for each component with a total of no more than three errors. STS: <u>13b(1)</u> , <u>13c</u> , <u>13d(1)</u> Meas: ~~W~~ , PC			(1.5/.5)
	(1) Condensers (2) Evaporators (3) Receivers			
	c. Given the names of three types of compressors, explain the basic operating principle of each with no more than two errors. STS: <u>13a(1)(a)</u> , <u>13a(1)(b)</u> , <u>13a(1)(c)</u> , <u>13a(1)(d)</u> Meas: ~~W~~ , PC			(2/.5)
	(1) Reciprocating (2) Rotary (3) Centrifugal			
	d. Given six basic facts stating the purpose, use, and operating principle of heat exchangers and oil separators, match the facts with the unit. No more than two errors permitted. STS: <u>13e(1)</u> , <u>13e(2)</u> Meas: ~~W~~ , PC			(1/.5)
	(1) Heat exchangers (2) Oil separators			
	e. List the steps required for servicing an evaporator, condenser, and oil separator with no more than two errors. STS: <u>13b(2)</u> , <u>13d(2)</u> , <u>13e(3)</u> Meas: ~~W~~ , PC			(1/.5)
	(1) Evaporator			
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COURSE CONTENT

(2) Oil separator

(3) Condenser

f. Given a list of refrigerant equipment accessories and a list of basic facts related to them, match the facts to the accessories with 80% accuracy. STS: 13e(5) Meas: ~~M~~, PC (1.5/.5)

(1) MGA

(2) Charging cylinder

(3) Cylinders, storage

(4) Dollies

g. State the types, purpose, and use of desiccants with no more than two errors. STS: 13e(4) Meas: ~~M~~, PC (1/.5)

(1) Types of desiccants

(2) Purpose of desiccants

(3) Use of desiccants

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SW J3ABR54530 001-II-7, Refrigeration Components and Accessories (DS)

WB J3ABR54530 001-II-7, Refrigeration Components and Accessories

Commercial Text, Modern Refrigeration and Air Conditioning

Audiovisual Aids

Charts, Set, Refrigeration System Components and Accessories

Transparencies, Set, Mechanical Refrigeration Components

Training Equipment

Trainer, Refrigeration Oil Separator

Trainer, Refrigeration Service Valve

Trainer, Manifold Gauge Assembly

Training Methods

Lecture/Discussion (5.5 hrs)

Performance (3 hrs)

Directed Study (3 hrs)

Instructional Guidance

Discuss each refrigeration component and accessory, emphasizing the type maintenance required. Directed Study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.

5. Written Test and Test Critique

1.5/0

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Fundamentals				
1.	COURSE CONTENT			2. TIME
6.	Basic Refrigeration			12/3
	a. Using a refrigeration trainer, copper tubing/pipe, and common hand tools and special tools provided, fabricate four refrigerant lines and install them. Three of the four must not have kinks or leaks. Clean the hand tools and replace them in the tool box. Only one error in selection, use and maintenance of tools allowed. STS: <u>7a</u> , <u>9a</u> , <u>9b</u> , <u>9c</u> , <u>9d</u> , <u>9f</u> Meas: ~~W~~ , PC			(3/.5)
	(1) Selection and use of hand tools (2) Maintenance of hand tools (3) Identifying size and type of copper tubing/pipe (4) Measuring and cutting of copper tubing/pipe (5) Bending of copper tubing (6) Flaring of copper tubing (7) Identifying types and sizes of refrigeration fittings			
	b. Given three randomly selected items of refrigeration equipment, list the steps for installation with no more than two errors. STS: <u>14b</u> Meas: ~~W~~ , PC			(3/.5)
	(1) Sight glass (2) Filter dryer (3) Receiver (4) Condenser (5) Compressor			
	c. Using a refrigeration trainer, and equipment provided, locate and repair the refrigerant leaks with no more than one assist from the instructor. STS: <u>14c</u> , <u>14d</u> , <u>14e</u> , <u>14h</u> , <u>14i</u> , <u>14n</u> , <u>14o</u> Meas: ~~W~~ , PC			(3/1)
	(1) Preoperational check of refrigeration equipment			
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COURSE CONTENT

- (2) Operation of refrigeration equipment
- (3) Positioning of the king and service valves
- (4) Manifold gauge assembly and its use
- (5) Leak detectors and their use
- (6) Repairing leaks

d. Using a refrigeration trainer and tools provided, purge, evacuate, charge and pump down the system with no more than two assists from the instructor. STS: 14d, 14e, 14h, 14i, 14j, 14k, 14l, 14m Meas: ~~W~~, P.C

(3/1)

- (1) Purpose of purging
- (2) Method of purging
- (3) Purpose of evacuating
- (4) Service valve and MCA valve positions for evacuating
- (5) Installation, operation and removal of a vacuum pump
- (6) Purpose of charging
- (7) Service valve and MCA positions for charging
- (8) Charging methods for a simple refrigeration system
- (9) Interpreting gauge readings and performing an operational check of a simple refrigeration system
- (10) Pumping down procedures for a simple refrigeration system

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SW J3ABR54530 001-II-6, Basic Refrigeration (DS)

WB J3ABR54530 001-II-6, Basic Refrigeration

Commercial Text, Modern Refrigeration and Air Conditioning

Audiovisual Aids

Charts, Set, Refrigeration System

Training Film, 27634, Refrigeration - Evacuating and Charging

COURSE CONTENT

Training Equipment

Trainer, Simple Refrigeration System

Bench Item, Vacuum Pump

Special Equipment: Manifold Gauge Assembly, Refrigerant Cylinder, Halide Leak Detector, Soap Bubble Solution, Electronic Leak Detector

Training Methods

Lecture/Discussion (4.5 hrs)

Demonstration (1 hr)

Performance (6 hrs)

Training Film (.5 hr)

Directed Study (3 hrs)

Instructional Guidance

Discuss projects to be performed by students then review procedures immediately prior to performance. Allow practice time as needed and as time is available prior to evaluation. Directed Study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Fundamentals				
1.	COURSE CONTENT			2. TIME
7. Compressor Checks and Trouble Analysis				16.5/5
a. Given the information, list the steps required to replace four randomly selected parts of a compressor with no more than two errors. STS: <u>13a(2)</u> Meas: ~~W~~ , PC				(4/1)
(1) Valves (2) Piston (3) Connecting rod (4) Crankshaft (5) Head (6) Service valves (7) Wrist pin (8) Shaft seals				
b. Given a small compressor and common hand tools, remove the compressor head and inspect and replace the valves with assistance from the instructor. STS: <u>14g</u> Meas: ~~W~~ , PC				(2/1)
(1) Procedures for valve replacement (2) Valve types and uses				
c. Given the oil and equipment required, service the compressor on a refrigeration trainer with instructor assistance. STS: <u>13a(4)</u> Meas: ~~W~~ , PC				(2/.5)
(1) Removal of refrigerant from oil (2) Positioning service valves (3) Pump down (4) Oil plug removal				
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COURSE CONTENT

- (5) Oil level checking
- (6) Addition of oil as needed

d. Using a refrigeration trainer, perform a preoperational check, position the king and service valves, and operate the system, using the MGA to confirm normal operation with instructor assistance. (2.5/.5)
STS: 14c, 14d, 14e, 14h, 14i Meas: ~~W~~, P C

- (1) Preoperational check
- (2) Positioning king and service valves
- (3) System operation
- (4) Manifold gauge assembly
- (5) Checking abnormal pressures

e. Using a refrigeration trainer, inspect the operation of the refrigeration accessories and compressor for proper operation and rotation with instructor assistance. STS: 13a(3), 13e(6), 22e (1.5/0)
Meas: ~~W~~, P C

- (1) Inspection of refrigeration accessories
- (2) Compressor checks

f. Using a refrigeration trainer, troubleshoot the system and perform equipment maintenance, with instructor assistance. STS: 14f, 22c(1), 22c(2), 22c(3), 22c(4), 22c(5) (4.5/2)
Meas: ~~W~~, P C

- (1) Equipment maintenance
- (2) Troubleshooting system

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SW J3ABR54530 001-II-7, Compressor Checks and Trouble Analysis (DS)
WB J3ABR54530 001-II-7, Compressor Checks and Trouble Analysis
Pressure Temperature Chart, Commercial Diagram
Commercial Text, Modern Refrigeration and Air Conditioning

Audiovisual Aids

Charts, Set, Refrigeration System, Pressure Temperature

COURSE CONTENT

Training Equipment

Trainer, Simple Refrigeration System

Special Equipment: Manifold Gauge Assembly, Halide Leak Detector

Training Methods

Lecture/Discussion (5 hrs)

Demonstration (2 hrs)

Performance (9.5 hrs)

Directed Study (5 hrs)

Instructional Guidance

Caution students not to tighten oil plug too tight. Use ATC Form 98 to appraise accomplishment of criterion objectives. Directed Study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.

8. Written Test and Test Critique

1.5/0

9. Physical Conditioning - Days 13, 15, 18, and 20

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Metering Devices, Motor Controls, Domestic and Commercial Refrigeration				
1.	COURSE CONTENT			2. TIME
1. Metering Devices				9/3
a. Given the information, state the operating principle of capillary tubes, automatic and thermostatic expansion valves, and special metering devices with no more than three errors. STS: <u>15b(1)(a)</u> , <u>15b(1)(b)</u> , <u>15b(1)(c)</u> Meas: ~~M~~ , PC				(6/1)
(1) Categories of metering devices (2) Operating principle of capillary tubes (choke tubes) (3) Special metering devices (4) Automatic expansion valves (constant pressure valves) (5) Thermostatic expansion valves				
b. Working as a member of a team and using a refrigeration trainer, remove the expansion valve, replace and adjust it to maintain the specified superheat with instructor assistance. STS: <u>15b(5)(a)</u> , <u>15b(5)(c)</u> , <u>15b(5)(d)</u> Meas: ~~M~~ , PC				(3/2)
(1) Removal procedures (2) Inspection (3) Re-installation (4) Operation (5) Superheat adjustment				
SUPPORT MATERIALS AND GUIDANCE				
<u>Student Instructional Materials</u> SW J3ABR54530 001-III-1, Metering Devices(PS) WB J3ABR54530 001-III-1, Metering Devices Commercial Text, Modern Refrigeration and Air Conditioning				
<u>Audiovisual Aids</u> Chart, Set, Metering Devices Transparencies, Set, Metering Devices				
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COURSE CONTENT

Training Film: 27687, Automatic Expansion Valve
Training Film: 27688, Refrigeration Expansion Valve Thermostatic
Valve Operation

Training Equipment

Trainer, Motor Control and Refrigeration Accessories
Trainer, Thermostatic Expansion Valve Tester

Training Methods

Lecture/Discussion (4 hrs)
Demonstration (1 hr)
Performance (4 hrs)
Directed Study (3 hrs)

Instructional Guidance

It will necessary in most cases for at least two individuals to work simultaneously on the motor control and refrigeration accessories trainer. Observe the work of each student to ensure that each one accomplishes the significant parts of the criterion. Before verification, the work must be accomplished and the workbook completed to your satisfaction. Intersperse the performance as you deem appropriate for the class being taught. Directed Study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Metering Devices, Motor Controls, Domestic and Commercial Refrigeration				
1.	COURSE CONTENT			2. TIME
2.	Motor Controls			9/2
	a. Given a list of motor controls and safety controls, explain the purpose and principle of operation of each component. 80% of the list must be completed correctly. STS: <u>15a(1)</u> Meas: ~~W~~ , PC			(4/0)
	(1) Thermal (2) Pressure (3) Operating principle			
	b. Working as a member of a team, and using a refrigeration trainer, remove the motor and safety controls from the circuit, reinstall, adjust and calibrate to the setting specified by the instructor. Instructor assistance permitted. STS: <u>15a(3)</u> , <u>15a(4)</u> , <u>15a(5)</u> , <u>17c(4)</u> Meas: ~~W~~ , PC			(5/2)
	(1) Thermostat setting terms (2) Control settings (3) Control installation (4) Calibration of controls (5) Servicing motor controls			
SUPPORT MATERIALS AND GUIDANCE				
<u>Student Instructional Materials</u> SW J3ABR54530 001-III-3, Motor Controls(DS) WB J3ABR54530 001-III-3, Motor Controls Commercial Text, Modern Refrigeration and Air Conditioning				
<u>Audiovisual Aids</u> Chart, Set, Motor Controls Transparencies, Set, Motor Controls				
<u>Training Equipment</u> Trainer, Motor Control and Refrigeration Accessories Multimeter				
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COURSE CONTENT

Training Methods

Lecture/Discussion (4 hrs)

Demonstration (1 hr)

Performance (4 hrs)

Directed Study (2 hrs)

Instructional Guidance

It will be necessary in most cases for at least two individuals to work simultaneously on the motor control and refrigeration accessories trainer. Observe the work of each student to ensure that each one accomplishes the significant parts of the criterion. Before verification, the work must be accomplished and the workbook completed to your satisfaction. Intersperse the performance as you deem appropriate for the class being taught. Directed Study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Metering Devices, Motor Controls, Domestic and Commercial Refrigeration				
1. COURSE CONTENT				2. TIME
3. Troubleshooting				10.5/3
a. Working as a member of a team, and using a refrigeration trainer, isolate two instructor induced motor control/safety device malfunctions with instructor assistance. STS: <u>15a(2)</u> Meas: ~~W~~ , P C				(4/1)
(1) Troubles (2) Corrective action				
b. Working as a member of a team, and using a refrigeration trainer, troubleshoot the system to locate and correct one instructor induced malfunction relating to: dirty strainers, restricted refrigerant lines, condenser or evaporator fans, abnormal low and high side pressures, and refrigerant controls. Instructor assistance permitted. STS: <u>15b(2)</u> , <u>15b(5)(b)</u> , <u>15b(5)(c)</u> , <u>22c(1)</u> , <u>22c(2)</u> , <u>22c(3)</u> , <u>22c(4)</u> Meas: ~~W~~ , P C				(4.5/2)
(1) Electrical measurement (2) Normal pressures (3) High head pressure (4) Low head pressure (5) Low, low pressure (6) Bad compressor valves				
c. Working as a member of a team, and using a refrigeration trainer, isolate one instructor induced malfunction concerning a dirty filter, with instructor assistance. STS: <u>22c(5)</u> Meas: ~~W~~ , P C				(2/0)
(1) Indications of a dirty filter				
SUPPORT MATERIALS AND GUIDANCE				
<u>Student Instructional Materials</u> SW J3ABR54530 001-III-3, Troubleshooting(DS) WB J3ABR54530 001-III-3, Troubleshooting Commercial Text, Modern Refrigeration and Air Conditioning				
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COURSE CONTENT

Training Equipment

Trainer, Motor Control and Refrigeration Accessories
Multimeter

Training Methods

Lecture/Discussion (1.5 hrs)
Performance (9 hrs)
Directed Study (3 hrs)

Instructional Guidance

It will be necessary in most cases for at least two individuals to work simultaneously on the motor control and refrigeration accessories trainer. Observe the work of each student to ensure that each one accomplishes the significant parts of the criterion. Before verification, the work must be accomplished and the workbook completed to your satisfaction. Intersperse the performance as you deem appropriate for the class being taught. Directed Study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.

4. Written Test and Test Critique

1.5/0

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Metering Devices, Motor Controls, Domestic and Commercial Refrigeration				
1.	COURSE CONTENT			2. TIME
5.	Domestic and Commercial Refrigeration			15/3
a. Given twenty incomplete statements relevant to the operating principles and construction features of domestic freezers, refrigerators, ice cream cabinets, reach-in boxes, water coolers, and ice machines, complete sixteen of the statements correctly. STS: <u>17a(1)</u> , <u>17a(2)</u> , <u>17a(3)</u> , <u>17a(4)</u> , <u>17a(5)</u> , <u>17a(6)</u> Meas: ~~W~~ , PC				(6/1)
(1) Operating principles of capillary tube system (2) Construction features of domestic/small commercial systems (3) Domestic refrigerator and freezer operating systems (4) Ice cream cabinets (5) Water coolers				
b. Don the protective equipment required for handling refrigerants with instructor assistance. STS: <u>3h(5)</u> Meas: ~~W~~ , PC				(1/0)
(1) Refrigerants				
c. Transfer refrigerant from storage container into a charging cylinder with instructor assistance. STS: <u>12b</u> Meas: ~~W~~ , PC				(1/0)
(1) Precautions (2) Procedure				
d. Working in pairs, evacuate and charge the assigned capillary tube system, using the method designated by the instructor, with instructor assistance. STS: <u>17c(2)</u> , <u>17c(3)</u> Meas: ~~W~~ , PC				(4/2)
(1) Weighted method (charging station) (2) Metered method (charge faster or muster) (3) Direct method (frost back) (4) Super heat method (5) Amperage method				
SUPERVISOR APPROVAL OF LESSON PLAN				
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COURSE CONTENT

- (6) Best methods for individual applications
- (7) Evacuation methods
 - (a) Deep vacuum
 - (b) Standing vacuum
 - (c) Triple evacuation
 - (d) Contaminated systems
- e. Given the information, state one of the two methods used to identify contaminated vacuum pump oil and state when the oil should be replaced. STS: 17e Meas: ~~W~~ (1/0)
 - (1) Vacuum pump maintenance
- f. Given the information, state the steps for cleaning a capillary tube with 70% accuracy. STS: 15b(4) Meas: ~~W~~ (.5/0)
 - (1) Identifying a restricted or plugged capillary tube
 - (2) Cleaning of a capillary tube
 - (3) Capillary tube cleaner
- g. Given a segment of a capillary tube and the necessary equipment, install the tube in a larger diameter tube. The installation shall be leak free, and the capillary tube shall extend into the larger tube 1 to 1.5 inches and be clean of obstructions, with instructor assistance. STS: 15b(3) Meas: ~~W~~, P C (1.5/0)
 - (1) Breaking of the capillary tube
 - (2) Installation of the tips
 - (3) Leak checks

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SW J3ABR54530 001-III-5, Domestic and Commercial Refrigeration (DS)
WB J3ABR54530 001-III-5, Domestic and Commercial Refrigeration
Commercial Text, Modern Refrigeration and Air Conditioning

Audiovisual Aids

Chart, Set, Domestic and Commercial Refrigeration

COURSE CONTENT

Training Equipment

Domestic Refrigerators
Domestic Refrigeration Demonstrator
Commercial Refrigeration Units
Multimeters, Amprobe/Voltmeter
Leak Detector, Electronic
Charging Station
Vacuum Pump
Turbo Torch Soldering Equipment

Training Methods

Lecture/Discussion (5 hrs)
Demonstration (1 hr)
Performance (9 hrs)
Directed Study (3 hrs)

Instructional Guidance

Stress safety when working on electrical mechanical equipment. Use ATC Form 98 to appraise accomplishment of criterion objectives. Directed Study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Metering Devices, Motor Controls, Domestic and Commercial Refrigeration				
1. COURSE CONTENT		2. TIME		
6. Hermetic and Semi-Hermetic Compressor Systems a. Using special test equipment, check a hermetic/semi-hermetic compressor for electrical malfunctions, with instructor assistance. STS: <u>7c, 13a(5)</u> Meas: ~~W~~ , P C (1) Terminal identification (2) Motor analyzer/start kit (3) Jumper cord b. Using electrical test equipment, check the unit designated by the instructor for electrical shorts, current flow and proper operation of start relay with instructor assistance. STS: <u>22b(1), 22b(2), 22b(3)</u> Meas: ~~W~~ , P C (1) Starting relays (2) Checking for shorts (3) Checking current flow c. Given a list of the types of ice makers/machines, state the operating principle and construction features of each. List will be complete with 80% accuracy. STS: <u>17a(7)</u> Meas: ~~W~~ , PC (1) Ice makers, definition (2) Major types of ice makers and construction features (3) Principle of operation (4) Ice machines, definition (5) Types of ice machines and their construction features (6) Principle of operation SUPPORT MATERIALS AND GUIDANCE Student Instructional Materials SW J3ABR54530 001-III-6, Hermetic and Semi-Hermetic Compressor Systems(DS)		13.5/5 (3/2) (7/1) (3.5/2)		
SUPERVISOR APPROVAL OF LESSON PLAN				
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COURSE CONTENT

WB J3ABR54530 001-III-6, Hermetic and Semi-Hermetic Compressor Systems
Commercial Text, Modern Refrigeration and Air Conditioning

Audiovisual Aids

Charts, Set, Starting Relays

Transparencies: Set, Starting Relays

Training Film: 27843, Compressors, Hermetic and Semi-hermetic - Electrical

Training Film: 27842, Compressors, Hermetic and Semi-hermetic - Starting
Relay Circuits

Training Equipment

Trainer, Current Relay

Trainer, Potential Relay

Trainer, Refrigeration Compressor

Trainer, Hermetic Refrigeration Compressor

Domestic Refrigerators and Commercial Refrigeration Units

Multimeter

Clamp-on AC Ampere Meter

Special Equipment: Test Cord, Hermetic Compressor, Motor Start Analyzer,
Solid State Relay, Current Relay, Potential Relay

Training Methods

Lecture/Discussion (5 hrs)

Demonstration (1 hr)

Performance (7.5 hrs)

Directed Study (5 hrs)

Instructional Guidance

Insure students remove their jewelry. Use ATC Form 98 to appraise accomplishment of criterion objectives. Directed Study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.

7. Written Test and Test Critique

1.5/0

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Metering Devices, Motor Controls, Domestic and Commercial Refrigeration				
1. COURSE CONTENT				2. TIME
8. Large Commercial Refrigeration Systems				28,5/8
a. Given the information, state the construction features and operating principle of walk-in boxes and cold storage plants, with 80% accuracy. STS: <u>17a(8)</u> , <u>17a(9)</u> Meas: ~~M~~ , PC				(3/1)
(1) Construction features (2) Operating principle				
b. State the steps required to maintain the defrost system used in commercial units with 80% accuracy. STS: <u>17d</u> Meas: ~~M~~ , PC				(3/0)
(1) Off-cycle system (2) Electric system (3) Hot gas system (4) Water (tap or heated) (5) Defrost timers				
c. Given the information, state the construction features and operating principle of large reach-in boxes, display cases, and ice cream cabinets with 80% accuracy. STS: <u>17a(4)</u> , <u>17a(5)</u> , <u>17a(6)</u> Meas: ~~M~~ , PC				(2/1)
(1) Reach-in boxes (2) Display cases (3) Ice cream cabinets				
d. Given the information, state the construction features and operating principle of multiple evaporator and multiple compressor systems with 80% accuracy. STS: <u>16a</u> Meas: ~~M~~ , PC				(2/1)
(1) Multiple evaporator system (2) Multiple compressor system				
SUPERVISOR APPROVAL OF LESSON PLAN				
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COURSE CONTENT

- e. Given the information, list the procedures for installing a commercial refrigeration unit with 80% accuracy. STS: 17b (2/0)
Meas: W, PC
- (1) Physical installation
 - (2) Preoperational check
 - (3) Operational check
- f. Given the information, list the procedures for installing multiple compressor and multiple evaporator systems with 60% accuracy. STS: 16b Meas: ~~W~~, PC (2/.5)
- (1) Multi-compressor
 - (2) Multi-evaporator
- g. Given the information, state the purpose and principle of operation of evaporator pressure regulator valves with 80% accuracy. STS: 16d Meas: ~~W~~, PC (2/.5)
- (1) Purpose of EPRs
 - (2) Types and principle of operation
- h. Given the operating instructions and working as a member of a team, operate multi-evaporator and multi-compressor systems with instructor assistance. Adjust the evaporator pressure regulator valves on a multi-evaporator system to maintain temperatures of 45°F, 40°F, and the coldest box 35°F to 45°F using the low pressure motor control. All temperatures are $\pm 2^\circ\text{F}$, with instructor assistance. STS: 16c, 16e Meas: ~~W~~, PC (10.5/4)
- (1) Operating multi-evaporator systems/single/multi-temp
 - (2) Adjusting the EPR/multi-temp
 - (3) Problems associated with the EPR
 - (4) Operating multi-compressor systems
- i. Given the information, list the steps in isolating a trouble in a multiple refrigeration system with no more than two errors. STS: 16f (.5/0)
Meas: ~~W~~, PC
- (1) Troubleshooting multiple refrigeration systems

COURSE CONTENT

j. Given the information, state the steps for cleaning and replacing refrigeration accessories with no more than two errors. (.5/0)
STS: 13e(7), 13e(8) Meas: ~~M~~

(1) Cleaning

(2) Replacing

k. Given the information, list the steps required for adjusting the door seal and replacement of defective parts on commercial refrigeration units, no more than two errors permitted. (.5/0)

STS: 17c(1), 17c(5) Meas: ~~M~~, PC

(1) Door seals

(2) Replacement of parts

l. Given the information, state the steps involved in using plans or drawings to determine the location of refrigeration units and components with no more than two errors. STS: 22a Meas: ~~M~~, PC (.5/0)

(1) Selection of drawing or plan

(2) Identification of symbols

(3) Orientating drawing

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SW J3ABR54530 001-III-8, Large Commercial Refrigeration Systems (DS)

WB J3ABR54530 001-III-8, Large Commercial Refrigeration Systems

Commercial Text, Modern Refrigeration and Air Conditioning

Audiovisual Aids

Chart, Set, Large Commercial Refrigeration Systems

Transparencies: Set, Large Commercial Refrigeration Systems

Training Equipment

Trainer, Multiple Evaporator Refrigeration System

Trainer, Multiple Compressor System

Demonstrator, Solenoid Valve

Tool Kit

Trainer, Open Type Display Case

Trainer, Reach-in Refrigerator

Trainer, Ice Cream Cabinet

Trainer, Water Cooler Drinking Fountain

Trainer, Water Dispenser

Trainer, Ice Machine Flake

Trainer, Ice Machine Cube

Trainer, Walk-In Refrigerator (Freezer and Medium Temperature)

COURSE CONTENT

Training Methods

Lecture/Discussion (15 hrs)

Demonstration (1.5 hrs)

Performance (12 hrs)

Directed Study (8 hrs)

Instructional Guidance

It will be necessary for at least two individuals to work simultaneously on the multiple evaporator refrigeration system trainer. Observe the work of each student to ensure that each one accomplishes the significant parts of the criterion. Before verification, the work must be accomplished and the workbook completed to your satisfaction. Intersperse the performance as you deem appropriate for the class being taught. Directed Study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.

- | | |
|---|-----|
| 9. Written Test and Test Critique | 1.5 |
| 10. Physical Conditioning - Days 23, 25, 28, 30, 33, and 35 | 6 |

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE		
BLOCK TITLE		COURSE TITLE		
Fundamentals of Air Conditioning		Refrigeration and Cryogenics Specialist		
1.	COURSE CONTENT		2. TIME	
1.	Civil Engineering Maintenance Management		1/.5	
	a. Using material provided, identify the basic facts and terms relating to Civil Engineering Maintenance Management Functions, with 80% accuracy. STS: <u>6a(3)</u> , <u>6a(4)</u> , <u>6b(1)</u> , <u>6b(2)</u> , <u>6f</u> Meas: ~~W~~ , PC (1) Work identification (a) Work request (b) Service calls (2) BCE Work Authorization (a) BCE work orders (b) BCE job orders (3) Management and utilization of material resources (4) <u>Engineered Performance Standards</u> SUPPORT MATERIALS AND GUIDANCE		(1/.5)	
Student Instructional Materials				
SW J3ABR54530 001-IV-1, Civil Engineering Maintenance Management(OS)				
WB J3ABR54530 001-IV-1, Civil Engineering Maintenance Management OS AFS S4, S5 and S6, <u>Engineered Performance Standards</u>				
Training Methods				
Lecture/Discussion (.5 hr)				
Performance (.5 hr)				
Directed Study (.5 hr)				
Instructional Guidance				
Evaluate knowledge of non-performance criterion objectives by using an Instructor Appraisal Worksheet.				
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PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Fundamentals of Air Conditioning				
1. COURSE CONTENT				2. TIME
2. Fundamentals				11/2.5
a. Given a series of incomplete statements, explain basic facts concerning the types and purpose of air conditioning equipment, and state the principles of air conditioning fundamentals with 80% accuracy. STS: <u>19a</u> , <u>19b</u> Meas: ~~W~~				(1/0)
(1) Fundamentals (2) Temperature control equipment (3) Humidity control equipment (4) Air filtration equipment (5) Air circulation equipment				
b. Using material provided, list the procedures for installing air conditioning equipment, and identify the process for assuring the security of mounting of refrigeration, water, electrical lines, and system components, with 70% accuracy. STS: <u>19f</u> , <u>22c(7)</u> Meas: ~~W~~				(1/0)
(1) Installation of air conditioning equipment (a) Cooling equipment (b) Humidity control equipment (c) Filters (d) Fans (2) Security of mounting (a) Refrigeration lines (b) Water lines (c) Electrical lines (d) System components				
c. Using a psychrometer, determine the wet and dry bulb temperatures of the air in a classroom, and using those temperatures, plot dewpoint temperature, relative humidity, specific humidity, and heat content on a				(2/0.5)
SUPERVISOR APPROVAL OF LESSON PLAN				
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COURSE CONTENT

psychrometric chart, with instructor assistance. STS: 19c, 19d(1), 19d(2), 19d(3)
Meas: ~~W~~, PC

- (1) Wet bulb temperature
- (2) Dry bulb temperature
- (3) Use of psychrometer
- (4) Dewpoint temperature
- (5) Relative and specific humidity
- (6) Heat content
- (7) Use of psychrometric chart

d. Using material provided, state simple facts relating to installation of insulating materials with 80% accuracy. STS: 18 Meas: ~~W~~, PC (1/0)

- (1) Installation of insulating materials

- (a) Bulk
- (b) Batt

- (2) Safety

e. Given the information, identify types and state the purpose of air filters with no more than two errors. STS: 19q(1) Meas: ~~W~~, PC (.5/0.25)

- (1) Purpose of air filters
- (2) Types of air filters

f. Given the information, state the procedures for cleaning and replacing air filters with 80% accuracy. STS: 19q(2), 19q(3) Meas: ~~W~~, PC (.5/0)

- (1) Cleaning filters
- (2) Replacing filters

g. Given the information, identify the types and state the applications of fans, with no more than two errors. STS: 19o(1) Meas: ~~W~~, PC (.5/0.5)

- (1) Types of fans
 - (a) Radial
 - (b) Axial
- (2) Applications of fans

COURSE CONTENT

h. Given the information, determine the procedures for installing and servicing fans, and list the methods for aligning drive belts and pulleys, with 80 percent accuracy. STS: 19o(2), 19o(3), 19o(4) Meas: ~~W~~, PC (1/0.5)

- (1) Installation of fans
- (2) Servicing fans
- (3) Aligning drive belts and pulleys

i. Given information, compare the relationship between the types of airflow instruments, state their purpose, and explain their principles of operation, with 70 percent accuracy. STS: 19p(1) Meas: ~~W~~, PC (1/0.25)

- (1) Purpose of air flow instruments
- (2) Types of air flow instruments
 - (a) Anemometer
 - (b) Velometer
 - (c) Manometer
- (3) Principles of operation

j. Given the information, explain the procedure for using instruments to determine the amount of air flow in an air conditioning system with not more than two errors. STS: 19p(2) (Meas: ~~W~~, PC) (1/0.25)

- (1) Determining amount of air flow
 - (a) Anemometer
 - (b) Velometer
 - (c) Manometer

k. Given the information, state basic facts concerning balancing the air distribution in an air conditioning system, with 80 percent accuracy. STS: 19j, 19k Meas: ~~W~~, PC (.5/0.25)

- (1) Determining air volume required for each area
- (2) Adjustment of the system and air distribution system

COURSE CONTENT

1. Given information, explain the procedures for maintaining fresh air supply systems, state the methods for checking for excessive leakage in air ducts, and inspecting ducts. STS: 19q(4), 19q(5), 22c(6) Meas: ~~★~~, PC (1/0)

- (1) Maintaining fresh air supply systems
- (2) Excessive leakage in air ducts
- (3) Inspecting ducts

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SW J3ABR54530 001-IV-2, Fundamentals(05)

WB J3ABR54530 001-IV-2, Fundamentals

Commercial Text, Modern Refrigeration and Air Conditioning

FO J3ABR54530 001-IV, Psychrometric Chart

Audiovisual Aids

Transparency Set, Psychrometrics

Chart, Psychrometrics

Training Equipment

Trainer, Insulation Demonstrator

Psychrometer

Velometer

Anemometer

Manometer

Training Methods

Lecture/Discussion (5.5 hrs)

Demonstration (0.5 hr)

Performance (5 hrs)

Directed Study (2.5 hrs)

Instructional Guidance

Evaluate criterion objectives by using the ATC Form 98. Criterion objective performance may be practiced before the performance measurement activity begins. Directed Study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE		
		Refrigeration & Cryogenics Specialist		
BLOCK TITLE				
Fundamentals of Air Conditioning				
1.	COURSE CONTENT			2. TIME
3.	Water Pumps			4/1
	a. Given the information, state basic facts or terms relating to the operating principles of centrifugal water pumps with no more than three errors. STS: <u>24a</u> Meas: ~~W~~ , PC			(1/0.5)
	(1) Operating principles of centrifugal water pumps			
	b. Given the information, explain the procedures used to install water pumps, align flexible couplings, replace pump packing, adjust pump packing, check the operation of water pumps, and repair water pumps with 60 percent accuracy. STS: <u>24b</u> , <u>24c</u> , <u>24d</u> , <u>24e</u> , <u>24f</u> , <u>24g</u> Meas: ~~W~~ , PC			(2/.5)
	(1) Installation of water pumps (2) Alignment of flexible couplings (3) Replacement of pump packing (4) Adjustment of pump packing (5) Checking water pump operation (6) Repairing water pumps			
	c. Given the information, state basic facts or terms concerning cross-connection/backflow prevention to protect potable water supplies, with no more than two errors. STS: <u>3k</u> Meas: ~~W~~ , PC			(1/0)
	(1) Cross-connection (2) Backflow prevention			
SUPPORT MATERIALS AND GUIDANCE				
Student Instructional Materials S/W DS J3ABR54530 001-IV-3, Water Pumps(DS) WB J3ABR54530 001-IV-3, Water Pumps Commercial Text, Modern Refrigeration and Air Conditioning				
SUPERVISOR APPROVAL OF LESSON PLAN				
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COURSE CONTENT

Audiovisual Aids

Transparencies, Set, Cooling Towers
Transparencies, Set, Water Pump
Transparencies, Set, Water Conditioning
Prenarrated Slides: ATS 54-21, Cooling Water Treatment

Training Equipment

Trainer, Centrifugal Water Pump
Trainer, Centrifugal Water Pump
Dial Indicator
Color Comparator
Laboratory Equipment

Training Methods

Lecture/Discussion (2.5 hrs)
Performance (1.5 hrs)
Directed Study (1 hr)

Instructional Guidance

Evaluate criterion objectives by using the ATC Form 98. Directed Study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE		
		Refrigeration & Cryogenics Specialist		
BLOCK TITLE				
Fundamentals of Air Conditioning				
1.	COURSE CONTENT			2. TIME
4.	Air Conditioning Maintenance			6.5/1.5
	a. Working as a member of a team, and using a window air conditioner, perform preoperational checks of the unit, with instructor assistance. (1/0.5) STS: <u>19e</u> Meas: ~~W~~ , PC			
	(1) Perform preoperational checks			
	(a) Condenser and evaporator			
	<u>1</u> Cleanliness			
	<u>2</u> Condition of fins			
	(b) Fan motor and fans			
	<u>1</u> Security of mounting			
	<u>2</u> Cleanliness			
	(c) Condensate drain			
	(d) Power supply			
	b. Working as a member of a team, and using a window air conditioner, perform equipment maintenance by charging the unit using the ambient dry bulb temperature method. The correct condensing pressure must be reached $\pm$ 5 PSI. STS: <u>19h</u> Meas: ~~W~~ , PC (2/.5)			
	(1) Calculating operating condensing pressure			
	(2) Charging procedure			
	c. Working as a member of a team, and using a window air conditioner, operate the unit and determine operating conditions with instructor assistance. STS: <u>19g</u> Meas: ~~W~~ , PC (1/.25)			
	(1) Condenser pressure and temperature			
	(2) Evaporator pressure and temperature			
	(3) Temperature difference across the evaporator			
SUPERVISOR APPROVAL OF LESSON PLAN				
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COURSE CONTENT

(4) Compressor amperage draw

(5) Fully active evaporator

d. Using the trainer provided, and working as a member of a team, (2.5/.25)
isolate instructor induced system malfunctions to the smallest replace-
able or repairable part. STS: 22d Meas: ~~W~~, PC

(1) Troubleshooting

(a) Refrigeration system

(b) Electrical system

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SW J3ABR54530 001-IV-4, Air Conditioning Maintenance (DS)

WB J3ABR54530 001-IV-4, Air Conditioning Maintenance

Commercial Text, Modern Refrigeration and Air Conditioning

Training Equipment

Trainer, Air Conditioner, Window

Trainer, Heating and Cooling, Residential

Trainer, Heat Pump

Amprobe, Clamp On

Vacuum Pump

Training Methods

Lecture/Discussion (3 hrs)

Demonstration (1 hr)

Performance (2.5 hrs)

Directed Study (1.5 hrs)

Instructional Guidance

Place adequate emphasis on safety precautions involved with refrigerant charging procedures. Evaluate criterion objectives by using ATC Form 98. Performance criterion objectives may be practiced before the performance measurement activity begins if time permits. During the performance measurement activity, assure that each student accomplishes a representative portion of the task. Directed Study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Fundamentals of Air Conditioning				
1.	COURSE CONTENT			2. TIME
1. Cooling Towers, Water Treatment, and Evaporative Condensers 6/2.5				
a. Given the information, identify terms and facts relating to the principle of operation, purpose of bleed off and make-up water, and methods of capacity control of cooling towers and evaporative condensers with no more than four errors. STS: <u>23a, 23b, 23f(1)</u> Meas: ~~W~~				(1.5/.5)
(1) Principles of operation of cooling towers (a) Types of cooling towers <u>1</u> Natural draft <u>2</u> Forced draft				
(2) Methods of cooling tower capacity control (a) Modulating the water flow (b) Modulating the air flow (c) Cycling the fan				
(3) Principles of operation of evaporative condensers				
(4) Evaporative condenser capacity control				
(5) Purpose of make-up water				
(6) Purpose of bleed-off				
b. Given the information, state the procedures for calculating water bleed-off with no more than one error. STS: <u>23c</u> Meas: ~~W~~				(.5/0)
(1) Calculating water bleed-off				
c. Given the information, state simple facts concerning the operation of cooling tower and evaporative condenser capacity controls with 80% accuracy. STS: <u>23f(2)</u> Meas: ~~W~~				(.5/1)
(1) Operation of cooling tower capacity controls				
(2) Operation of evaporative condenser capacity controls				
SUPERVISOR APPROVAL OF LESSON PLAN				
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COURSE CONTENT

d. Given the information, describe the procedures for installing and maintaining cooling towers and evaporative condensers with 80% accuracy. STS: 23d, 23e Meas: ~~W~~, PC (.5/0)

(1) Installation of cooling towers and evaporative condensers

(2) Maintenance of cooling towers and evaporative condensers

e. Given the information, state basic facts or terms relating to the application of evaporative condensers with 80% accuracy. STS: 23g Meas: ~~W~~, PC (.5/0)

(1) Application of evaporative condensers

f. Given the information, state the method of recognizing scale, corrosion, and algae with no more than two errors. STS: 25a(1), 25a(2), 25a(3) Meas: ~~W~~, PC (.5/0)

(1) Recognizing scale

(2) Recognizing corrosion

(3) Recognizing algae

COURSE CONTENT

g. Given the information, identify basic facts about the effects of scale, corrosion, and algae on an air conditioning system with 80% accuracy. STS: 25b Meas: ~~W~~ (.5/0)

- (1) Effects of scale
- (2) Effects of corrosion
- (3) Effects of algae

h. Given the information, state the procedure for chemically treating water for scale, corrosion, and algae with no more than two errors. STS: 25c(1), 25c(2), 25c(3) Meas: ~~W~~ (.5/1)

- (1) Determination of PH for water
- (2) Chemical treatment of water for scale
 - (a) Sodium zeolite water softening
 - (b) Phosphates
 - (c) Sulfuric acid
- (3) Chemical treatment of water for corrosion
 - (a) Phosphates
- (4) Chemical treatment of water for algae
 - (a) Calcium hypochlorite
 - (b) Copper sulfate

i. Given the information, state simple facts concerning the operation and adjustment of cooling tower water conditioning equipment with 80% accuracy. STS: 23h, 23i Meas: ~~W~~ (.5/0)

- (1) Drip feeder
 - (a) Operation
 - (b) Adjustment
- (2) Pot feeder
 - (a) Operation
 - (b) Adjustment

COURSE CONTENT

j. Given the information, list simple facts relating to the maintenance (.5/0)
of evaporative mechanical equipment with 70% accuracy. STS: 19i Meas: ~~W~~, PC

(1) Maintenance of evaporative mechanical equipment

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SW J3ABR54530 001-IV-5, Cooling Towers, Water Treatment, and Evaporative
Condensers (~~DS~~)

WB J3ABR54530 001-IV-5, Cooling Towers, Water Treatment, and Evaporative
Condensers

Commercial Text, Modern Refrigeration and Air Conditioning

Audiovisual Aids

Transparencies, Set, Cooling Towers, Water Treatment, and Evaporative
Condensers

Prenarrated Slides: ATS 54-21, Cooling Water Treatment

Training Equipment

Trainer, Centrifugal Air Conditioner

Color Comparator

Laboratory Equipment

Training Methods

Lecture/Discussion (3 hrs)

Performance (3 hrs)

Directed Study (2.5 hrs)

Instructional Guidance

Use ATC Form 98 to appraise accomplishment of criterion objectives. Directed
Study assignments will be accomplished outside the classroom, and will be
verified the following day by a written directed study examination.

- | | |
|--|-----|
| 6. Written Test and Test Critique | 1.5 |
| 7. Physical Conditioning, Days 38 and 40 | 2 |

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Air Conditioning Controls				
1.	COURSE CONTENT			2. TIME
1.	Air Compressing Equipment			1.5/0
	a. Given the information, state the types, purpose and operating principle of air compressing equipment used to support air conditioning systems. 80% accuracy must be attained. STS: <u>13f(1)</u> Meas: ~~✓~~			(1/0)
	(1) Types (2) Purpose (3) Principle of operation			
	b. Given a disordered list of steps necessary for the installation, replacement of defective parts, checking equipment operation, operator service, and maintenance of air compressing equipment, select the appropriate steps for each activity and place them in logical sequence. List must be completed with 80% accuracy. STS: <u>13f(2)</u> , <u>13f(3)</u> , <u>13f(4)</u> , <u>13f(5)</u> Meas: ~~✓~~			(.5/0)
	(1) Installation (2) Replacement of defective parts (3) Checking equipment operation (4) Operator service and maintenance			
SUPPORT MATERIALS AND GUIDANCE				
<u>Student Instructional Materials</u> SW J3ABR54530 001-V-1, Air Compressing Equipment (DS) WB J3ABR54530 001-V-1, Air Compressing Equipment Commercial Text, Modern Refrigeration and Air Conditioning				
<u>Audiovisual Aids</u> Transparencies, Set, Air Compressor				
<u>Training Equipment</u> Trainer, Air Compressor Control Air				
SUPERVISOR APPROVAL OF LESSON PLAN				
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COURSE CONTENT

Training Methods

Lecture/Discussion (.75 hr)

Performance (.75 hr)

Instructional Guidance

Stress safety around electrical and mechanical equipment.

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Air Conditioning Controls				
1.	COURSE CONTENT			2. TIME
2.	Pneumatic Controls			9/3
	a. Given the information, explain the purpose, use, and operating principle of pneumatic controls with 80% accuracy. STS: <u>15e(1), 15e(2)</u> Meas: ~~W~~ , PC			(4.5/1)
	(1) Terms (2) Types, purpose and use of pneumatic controls (3) Operating principle of pneumatic controls			
	b. Working as a member of a team and using a refrigeration controls trainer, calibrate the pneumatic thermostat to maintain a temperature specified by the instructor $\pm 4^{\circ}\text{F}$. STS: <u>15e(3)</u> Meas: ~~W~~ , PC			(2/1)
	(1) Calibration procedures			
	c. Working as a team member and using a refrigeration controls, locate two of three instructor induced malfunctions. Maintain the pneumatic equipment by repairing the malfunctions with instructor assistance. STS: <u>15e(4), 15e(5)</u> Meas: ~~W~~ , PC			(2/.5)
	(1) Troubleshooting pneumatic equipment (2) Maintaining pneumatic equipment			
	d. Given the information, state the operating principles of mechanical air dryers with no more than two errors. STS: <u>15e(6)</u> Meas: ~~W~~ , PC			(.5/.5)
	(1) Mechanical dryers			
SUPPORT MATERIALS AND GUIDANCE				
<u>Student Instructional Materials</u> SW J3ABR54530 001-V-2, Pneumatic Controls(DS) WB J3ABR54530 001-V-2, Pneumatic Controls Commercial Text, Modern Refrigeration and Air Conditioning				
<u>Audiovisual Aids</u> Transparencies, Set, Pneumatic Controls Chart, Set, Pneumatic Controls				
SUPERVISOR APPROVAL OF LESSON PLAN				
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COURSE CONTENT

Training Equipment

Trainer, Refrigeration Controls

Trainer, Dehydrator

Bench Items: Room Thermostat
Room Humidistat
Heating-Cooling Thermostat
Pneumatic Valve
Pneumatic Damper Operator
Pilot Positioner

Training Methods

Lecture/Discussion (4 hrs)

Demonstration (1 hr)

Performance (4 hrs)

Directed Study (3 hrs)

Instructional Guidance

As a safety precaution, students will remove all jewelry while completing performance. Use ATC Form 98 to appraise accomplishment of criterion objectives. Directed Study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Air Conditioning Controls				
1.	COURSE CONTENT			2. TIME
3.	Electrical Controls			9/2
	a. Given the information, explain the purpose, use, and operating principle of electrical controls with 80% accuracy. STS: <u>15c(1)(a)</u> , <u>15c(1)(b)</u> , <u>15c(2)</u> Meas: ~~W~~			(4/1)
	(1) Purpose (2) Use (3) Operating principle of two-position controls (4) Operating principle of modulating controls			
	b. Working as a member of a team and using a refrigeration controls trainer, calibrate a series 90 electrical control loop with instructor assistance. STS: <u>15c(3)</u> Meas: ~~W~~ , PC			(2/.5)
	(1) Calibration procedures			
	c. Working as a member of a team and using a refrigeration controls trainer, isolate two instructor induced electrical controls malfunctions with instructor assistance. STS: <u>15c(4)</u> Meas: ~~W~~ , PC			(2/.5)
	(1) Troubleshooting electrical controls			
	d. Given a disordered list of steps for replacing electrical controls, place them in logical order with 70% accuracy. STS: <u>15c(5)</u> Meas: ~~W~~			(1/0)
	(1) Safety considerations (2) Sequence			
SUPPORT MATERIALS AND GUIDANCE				
<u>Student Instructional Materials</u> SW J3ABR54530 001-V-3, Electrical Controls (DS) WB J3ABR54530 001-V-3, Electrical Controls				
<u>Audiovisual Aids</u> Transparencies, Set, Electrical Controls Charts, Set, Electrical Controls				
SUPERVISOR APPROVAL OF LESSON PLAN				
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COURSE CONTENT

Training Equipment

Trainer, Refrigeration Controls

Multimeter

Bench Items: Electrical Controller Series 40
Pressuretrol Series 90
Series 90 Control Motor
Series 80 Control Motor

Training Methods

Lecture/Discussion (4 hrs)

Demonstration (1 hr)

Performance (4 hrs)

Directed Study (2 hrs)

Instructional Guidance

Use ATC Form 98 to appraise accomplishment of criterion objectives. Directed Study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Air Conditioning Controls				
1.	COURSE CONTENT			2. TIME
4.	Electronic Controls			9/3
a. Given five basic electronic diagrams, draw lines to indicate current flow through the circuits. Three of the five circuits must be correct. STS: <u>15d(1)</u> Meas: ~~W~~ , PC				(3/.25)
(1) Current flow in P-type material (2) Current flow in N-type material (3) A P-N junction (4) Forward and reverse - BIAS (5) Junction transistors (Triode) (6) NPN transistors (7) PNP transistors				
b. Given a schematic of a bridge circuit describe its function and draw lines to indicate current flow through the device for one cycle. Two errors permitted. STS: <u>8f(1)(d)</u> , <u>15d(3)</u> Meas: ~~W~~ , PC				(1/0.5)
(1) Function of bridge circuits (2) Operation of bridge rectifiers (3) Operation of bridge control circuits				
c. Given a list of five electronic components, state their application to electronic controls. Four of the five must be correct. STS: <u>15d(2)</u> Meas: ~~W~~ , PC				(1/.25)
(1) Diode (2) PNP transistor (3) NPN transistor (4) Capacitor (5) Inductor (choke coil)				
SUPERVISOR APPROVAL OF LESSON PLAN				
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COURSE CONTENT

d. Given the information, trace the current flow through a simple amplifier circuit and state its purpose. Two errors permitted. (1/0.5)
STS: 15d(4) Meas: ~~W~~, PC

- (1) Purpose of amplifiers
- (2) Principle of operation

e. Given the information, state the purpose, use and operating principle of electronic control circuits with no more than two errors. (1/1)
STS: 15d(5), 15d(7) Meas: ~~W~~, PC

- (1) Purpose
- (2) Use
- (3) Operating principle

f. Given the information, state the operating principle of modulating electronic controls. Only one error permitted. STS: 15d(6) Meas: ~~W~~, PC (1/0.25)

- (1) Operating principle

g. Given the information, state the procedure for troubleshooting electronic controls and replacing the controls with no more than two errors. STS: 15d(9), 15d(10) Meas: ~~W~~, PC (.5/.25)

h. Using a modified Wheatstone Bridge Trainer, adjust the control point ± 1 microamp. STS: 15d(8) Meas: ~~W~~, PC (.5/0)

- (1) Circuit analysis
- (2) Adjustment procedures

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SW J3ABR54530 001-V-4, Electronic Controls (DS)

WB J3ABR54530 001-V-4, Electronic Controls

Audiovisual Aids

Transparencies, Set, Electronic Controls

Training Film: TF1-5250-A, Transistors - PN Junction Fundamentals

Training Equipment

Trainer, Modified Wheatstone Bridge

Trainer, Refrigeration Controls

COURSE CONTENT

Training Methods

Lecture/Discussion (5 hrs)

Demonstration (1 hr)

Performance (3 hrs)

Directed Study (3 hrs)

Instructional Guidance

As a safety precaution, students will remove all jewelry while completing performance. Use ATC Form 98 to appraise accomplishment of criterion objectives. Directed Study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.

- | | |
|---|-----|
| 5. Written Test and Test Critique | 1.5 |
| 6. Physical Conditioning - Days 43 and 45 | 2 |

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Commercial Air Conditioning				
1.	COURSE CONTENT			2. TIME
1.	Air Handlers			1.5/0.5
	a. Given a disordered list of steps required to replace air handler bearings, shafts, belts and pulleys; and adjustment of damper linkage, place the steps in order with no more than four errors. STS: <u>22f(3)</u> , <u>22f(4)</u> , <u>22f(5)</u> Meas: ~~W~~			(1.0/.25)
	(1) Construction features (2) Replacement of components (3) Damper adjustment			
	b. Given the information, state the steps for lubricating air handler bearings and checking the bearings, belts and pulley alignment with no more than three errors. STS: <u>22f(1)</u> , <u>22f(2)</u> Meas: ~~W~~			(.5/.25)
	(1) Lubrication (2) Bearings and belt checks (3) Pulley alignment check			
SUPPORT MATERIALS AND GUIDANCE				
<u>Student Instructional Materials</u> SW J3ABR54530 001-VI-1, Air Handlers (DS) WB J3ABR54530 001-VI-1, Air Handlers Commercial Text, Modern Refrigeration and Air Conditioning				
<u>Training Equipment</u> Trainer, Air Conditioner, 8½ ton/80 ton				
<u>Training Methods</u> Lecture/Discussion (1.5 hrs) Directed Study (.5 hr)				
<u>Instructional Guidance</u> Use workbook to appraise accomplishment of knowledge criterion objectives. Directed study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.				
SUPERVISOR APPROVAL OF LESSON PLAN				
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PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Commercial Air Conditioning				
1.	COURSE CONTENT			2. TIME
2.	Centrifugal Air Conditioning			11:5/2.5
	a. Select from a list of principles, those that apply to the operation of centrifugal air conditioning system with no more than two errors. STS: <u>21a</u> Meas: ~~W~~ , PC			(2/0.25)
	(1) Principles of operation			
	b. Given a flow diagram of the refrigerant, chilled water, and condenser water systems, indicate by designated colors and arrows the flow and direction of each system. No more than two errors permitted. STS: <u>21c</u> Meas: ~~W~~ , PC			(1/0.25)
	(1) Refrigerant flow (2) Chilled water flow (3) Condenser water flow			
	c. Given the information, state the steps in maintaining the chilled water system with no more than one error. STS: <u>191</u> Meas: ~~W~~ , PC			(1/0)
	(1) Evaporator tubes (2) Water treatment			
	d. Given the information, list the steps required for pressure checking the refrigeration systems with dry nitrogen. No more than two errors permitted. STS: <u>14p</u> Meas: ~~W~~ , PC			(1/0)
	(1) Pressure checking systems (2) Safety precautions			
	e. Given a disordered list of steps required for charging a centrifugal system with refrigerant, place the steps in order with no more than two errors. STS: <u>21b</u> Meas: ~~W~~ , PC			(1/0.5)
	(1) Charging centrifugal systems			
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COURSE CONTENT

f. Working as a member of a team and using a centrifugal system trainer, check, adjust and perform maintenance on the compressor and system controls with instructor assistance. (2/0.5)
STS: 21e, 21f, 21g Meas: ~~W~~, P C

- (1) Checks
- (2) Adjustments
- (3) Maintenance

g. Working as a member of a team and using a centrifugal system trainer, operate the purge recovery unit with instructor assistance. STS: 21h Meas: ~~W~~, P C (1.5/0.5)

- (1) Purge unit operation

h. Working as a member of a team and using a centrifugal system trainer, operate the compressor and perform the operational checks on the system while applying safety precautions pertaining to high intensity sound with instructor assistance. STS: 3h(3), 21d, 22e Meas: ~~W~~, P C (2/0.5)

- (1) Operation of centrifugal compressor
- (2) Operational checks
- (3) Safety precautions

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SW J3ABR54530 001-VI-2, Centrifugal Air Conditioning (DS)
WB J3ABR54530 001-VI-2, Centrifugal Air Conditioning
Commercial Text, Modern Refrigeration and Air Conditioning

Audiovisual Aids

Chart Set, Centrifugal Air Conditioning
Transparencies, Set, Centrifugal Air Conditioning

Training Equipment

Trainer, Air Conditioner, Centrifugal

Training Methods

Lecture/Discussion (6 hrs)
Demonstration (1 hr)
Performance (4.5 hrs)
Directed Study (2.5 hrs)

COURSE CONTENT

Instructional Guidance

Use workbook to appraise accomplishment of criterion objectives. Criterion objective task performance may be practiced before the performance measurement activity begins. Instructor assistance may be given on criterion objectives 3f, 3g and 3h as indicated by the workbook. During the task performance measurement activity relating to criterion objectives 3f, 3g, and 3h, assure that each student accomplishes a representative portion of the task. Directed Study assignments will be accomplished outside the classroom and will be verified the following day by a written directed study examination.

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Commercial Air Conditioning				
1. COURSE CONTENT				2. TIME
3. Absorption Air Conditioning				12.5/3.5
a. Using an Absorption System Trainer and an Absorption Cycle Schematic, label the major components and trace the flow of the solution and refrigerant. No more than 4 errors permitted. STS: <u>20a</u> , <u>20b</u> Meas: ~~W~~ , PC				(2.5/1)
(1) Absorption principles (2) Absorption terms (3) Major components (4) System configuration (5) Operating principles				
b. Given the information, state the procedures for leak testing the Absorption Air Conditioning System, with no more than 3 errors. STS: <u>20d(1)</u> , <u>20d(2)</u> Meas: ~~W~~ , PC				(1/0)
(1) Vacuum Test (2) Pressure Test				
c. Working as a team member, using an Absorption System Trainer and equipment provided, operate the system. While operating the system, record temperature and pressure readings on the system operation. No more than 2 errors permitted. STS: <u>20c</u> Meas: ~~W~~ , PC				(9/2.5)
(1) Preoperational checks (2) Starting procedures (3) Stopping procedures (4) Operating logs (5) Equilibrium chart (6) Purge operation				
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COURSE CONTENT

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials

SW J3ABR54530 001-VI-3, Absorption Air Conditioning Systems (DS)

WB J3ABR54530 001-VI-3, Absorption Air Conditioning Systems

Commercial Text: Modern Refrigeration and Air Conditioning

Audiovisual Aids

Transparencies, Set, Absorption Air Conditioning Systems

Training Equipment

Trainer, Air Conditioner, Absorption

Training Methods

Lecture/Discussion (4.5 hrs)

Demonstration (1 hr)

Performance (7 hrs)

Directed Study (3.5 hrs)

Instructional Guidance

Use ATC Form 98 to appraise accomplishment of criterion objectives. Criterion objective task performance may be practiced before the measurement activity begins if time permits. Directed Study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Commercial Air Conditioning				
1.		COURSE CONTENT		2. TIME
4.		Cylinder Unloaders and Humidity Control		4.5/1.5
		a. Given a list of ten statements, select three of the five which describe the operating principle of cylinder unloaders. STS: <u>13a(6)</u> Meas: ~~N~~ , PC		(1.5/.5)
		(1) Actuator		
		(2) Unloader		
		b. Working as a member of a team and using an air conditioner trainer, adjust the cylinder unloader to the value specified by the instructor with instructor assistance. STS: <u>13a(7)</u> Meas: ~~N~~ , PC		(1/.5)
		(1) Adjustment procedure		
		c. Given a list containing ten statements relative to the types and purpose of humidity control equipment, select three of the five which are correctly stated. STS: <u>19r(1)</u> Meas: ~~N~~ , PC		(1/.5)
		(1) Types		
		(2) Purpose		
		d. Given the information, state the adjustment procedure for humidity control equipment with no more than one errors. STS: <u>19r(2)</u> Meas: ~~N~~ , PC		(1/0)
		(1) Adjustment procedure		
SUPPORT MATERIALS AND GUIDANCE				
Student Instructional Materials				
SW J3ABR54530 001-VI-4, Cylinder Unloaders and Humidity Control(DS)				
WB J3ABR54530 001-VI-4, Cylinder Unloaders and Humidity Control				
Commercial Text, Modern Refrigeration and Air Conditioning				
Audiovisual Aids				
Transparencies, Set, Cylinder Unloader and Humidity Control				
Chart, Set, Cylinder Unloaders and Humidity Control				
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COURSE CONTENT

Training Equipment

Trainer, Air Conditioner

Amprobe

Training Methods

Lecture/Demonstration (2.25 hrs)

Demonstration (0.25 hrs)

Performance (2 hrs)

Directed Study (1.5 hrs)

Instructional Guidance

Place adequate emphasis on safety precautions around operating equipment, and working with live electrical circuits. Use ATC Form 98 to appraise accomplishment of criterion objectives. During the task performance measurement activity relation to criterion objective 4b, assure that each student accomplishes a representative portion of the task. Instructor assistance may be given on criterion objective 4b as indicated by the ATC Form 98. Criterion objective task performance may be practiced before the performance measurement activity begins.

Directed Study assignments will be accomplished outside the classroom, and will be verified the following day by a written directed study examination.

PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR			COURSE TITLE Refrigeration and Cryogenics Specialist	
BLOCK TITLE Commercial Air Conditioning				
1.	COURSE CONTENT			2. TIME
5. Security	a. Using ATC/SGE3ABR/OBR00001, determine classification and methods of preventing security violations, with no more than two errors. STS: <u>2a(1)</u> , <u>2a(2)</u> Meas: ~~W~~ , PC			0/1 (0/.5)
	b. Given a source document, identify the vulnerabilities associated with the refrigeration and cryogenics career field, with no more than two errors. STS: <u>2b(6)</u> Meas: ~~W~~ , PC			(0/.5)
SUPPORT MATERIALS AND GUIDANCE				
<u>Student Instructional Materials</u> ATC SG E3ABR/OBR00001, Communications Security SW J3ABR54530 001-VI-5, Vulnerabilities of AFSC 545X0 to Operations Security Violations				
<u>Training Methods</u> Directed Study (1 hr)				
<u>Instructional Guidance</u> Directed Study assignment will be accomplished outside the classroom and will be verified the following day by a written directed study examination.				
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PLAN OF INSTRUCTION/LESSON PLAN PART I				
NAME OF INSTRUCTOR		COURSE TITLE Refrigeration and Cryogenics Specialist		
BLOCK TITLE Commercial Air Conditioning				
1.	COURSE CONTENT			2. TIME
6.	Publications			3/0
	a. Select from a list of five definitions the one which defines the scope and application of technical order systems. STS: <u>4a</u> Meas: ~~W~~ , PC			(1.5/0)
	(1) Technical Order System			
	b. Use the Manufacturer's Manual to perform an inspection and one item of maintenance on the Absorption System Trainer with instructor assistance. STS: <u>4b</u> Meas: ~~W~~ , PC			(1.5/0)
	(1) Use of manual (2) Inspections (3) Maintenance			
SUPPORT MATERIALS AND GUIDANCE				
<u>Student Instructional Materials</u> SG AFS 54, 55, 56 Publications WB J3ABR54530 001-VI-6, Publications Technical Order Files				
<u>Training Methods</u> Lecture/Discussion (1.5 hrs) Performance (1.5 hrs)				
<u>Instructional Guidance</u> Use ATC Form 98 to appraise accomplishment of criterion objective 6a. Instructor assistance may be given on criterion objective 6b, as indicated by the ATC Form 98.				
7.	Written Test and Test Critique			1.5
8.	Course Critique and Graduation			1.5
9.	Physical Conditioning - Days 48 and 50			2
10.	End of Course Appointments and Predeparture Safety Briefing			2
SUPERVISOR APPROVAL OF LESSON PLAN				
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Technical Training

Refrigeration and Cryogenics Specialist

ELECTRICAL

October 1982



USAF TECHNICAL TRAINING SCHOOL
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

Designed for ATC Course Use
DO NOT USE ON THE JOB

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I-7	Schematic Interpretation and Electrical Troubleshooting	7-1

DIRECTED STUDY ASSIGNMENTS

TO BE COMPLETED PRIOR TO DAY:

	PAGES
2	<u>4-1</u> thru <u>4-8</u>
3	<u>4-9</u> thru <u>4-35</u>
4	<u>4-36</u> thru <u>4-44</u>
5	<u>4-45</u> thru <u>4-51</u>
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Supersedes SGS 3ABR54530-I-1, I-3 thru I-9, June 1981

ORIENTATION

OBJECTIVE

This study guide will acquaint you with the course organization, objectives, instruction and measurement programs, and with the organization of a typical civil engineering organization.

INTRODUCTION

This entire orientation study guide is an introduction. In it we will attempt to introduce you to the contents, policies, and objectives of the course and career field for which you have been selected. In our initial introduction we will attempt to cover the daily schedules, the instruction and measurement policies, the type of training materials used and other items of particular interest to you as an entering student. We will also acquaint you with the organization of a typical civil engineering organization. Above all, we want you to feel welcomed in our course and we will do everything we can to make your stay at Sheppard worthwhile and pleasant for you. The more you put into the course, the more you will get out of it.

Materials presented in the following pages will be under the major topic headings as follows:

- _____ Overview of Course Content
- _____ Responsibilities of Students
- _____ Relationship of Graduates Performance to Air Force Mission
- _____ Benefits of CCAF
- _____ Types & Use of Instructional Materials
- _____ Student Progress Policies
- _____ Student Relocation Program
- _____ Effective Study Techniques
- _____ Procedures for Shelter Exercises and Fire Evacuation Plan
- _____ Student Critique Program
- _____ Conservation of Resources
- _____ Disposition of Eliminees
- _____ TDY Personnel Processing

Overview of Course Contents

This course to which you have been assigned is organized in a manner to present you instruction in a progressive sequence. That is, fundamentals and principles are presented first and are followed by your practical performance to insure that you acquire both the knowledges and skills necessary to perform as an apprentice refrigeration and air-conditioning specialist. Your training begins with this orientation study guide and will proceed through the fundamentals of refrigeration fittings and shop equipment;

electrical fundamentals and circuits; refrigeration principles, controls, and accessories; domestic and commercial refrigeration units and systems; water testing treatment; refrigeration controls and systems; technical publications; communications security; and an introduction to Air Force management and training programs.

The established sequence of instruction has proven to be very effective over a long period of course conduct. Many students have completed the course successfully in its present form. You can also successfully complete it. It will require much effort on your part, but then anything worthwhile requires effort. Then, after graduation from this course, some of you will be selected to go to a follow-on course in cryogenics taught at Chanute AFB before you report to your assigned organization.

STUDENT RESPONSIBILITIES

Uniform for Attendance and Military Appearance

The uniform worn to school is prescribed by the base commander in accordance with AF regulations. Your uniform will consist of fatigues (long or short sleeves), fatigue caps, and brogans. Your squadron will be notified by the commandant of troops on a daily basis of any change of wearing apparel. All students will have clean, pressed fatigues, shined shoes, and be well groomed. Any discrepancies noticed by the instructor will be reported to the supervisor for corrective action.

Training Schedule

A schedule of the training activities will be explained by your instructor. To provide the best practical learning situation, the minimum instructional period is 30 minutes; the maximum time period for classroom activity where you are required to sit continuously is 60 minutes; and for laboratory (performance) activity, 100 minutes.

Breaks

Break schedules are posted on each classroom bulletin board. Your instructor will dismiss you for breaks and designate the outside break area. Your instructor will also designate an inside break area during inclement weather. All students must leave classrooms for the entire break period.

Facilities are provided enabling you to buy gum, candy, beverages, etc. In order to minimize fire hazard, your cigarette butts will be placed in butt cans (painted red) and trash placed in proper containers. Each student is responsible for keeping the break area clean.

Be sure to stay in the designated break area during break, do not loiter on sidewalks or in front of doors and be certain to obey all posted signs and follow the directions of the break monitor. Most of all, be sure and take your break--leave the classroom and relax.

Cleanup Responsibilities

All areas of instruction must be kept clean; therefore, it will be each student's responsibility to perform the cleanup assigned. During your tour of the course instructional areas, your instructor will have shown you where all cleaning supplies and utilities are located. The authorized cleanup time is 10 minutes prior to dismissal. To do a good job, cooperation and expediency are mandatory of all personnel.

Study Notebook

This very important item in your continuing education and training must be developed and maintained by you. No one else can make an effective notebook for you.

Like almost everything else worthwhile, making a good notebook takes time and work. Perhaps you can develop a very good method for yourself. One effective method is for you

to study your study guide assignment and make an outline of the major topics and subtopics, jotting down items which look important to you. This should be an informal form to begin with. After reviewing your study guide assignment and your rough notes, you should be prepared to participate in the classroom discussion of the subject.

During the classroom discussion, you should correct your material as required and add the important items identified by the instructor. You should also add to these notes during your performance exercises. Make sure you get down all the key elements from the training literature and from the instructor's discussions. This is the material you need for good course grades and satisfactory performance in the field.

RELATIONSHIP OF GRADUATES PERFORMANCE TO AIR FORCE MISSION

The modern refrigeration and cryogenics technician must be a well-trained and highly-skilled person. In civilian life, he or she is a well-paid person. You have been fortunate in having been selected to become this type of technician. It is important to you to study and work hard to take advantage of your opportunity. We will help you as much as possible; however, it is up to you to take care of your future. So work with us and together we will succeed.

BENEFITS OF CCAF

The American Council of Education receives copies of the training control documents for the course you are in, and all other courses of this type. They have evaluated these control documents and have arrived at the academic credits which can be granted for successful course completion. The number of semester hours for your course is now being established by the Community College of the Air Force. By the time you leave the service, you will be able to apply a definite number of semester hours credit to a related field of study at most educational institutions. As a rough estimate, it appears you can get somewhere in the neighborhood of 15 semester hours credit for successful course completion.

TYPES AND USE OF INSTRUCTIONAL MATERIAL

In order for you to participate actively throughout the course, you will be provided with:

Study Guides

These contain detailed information on subjects being covered throughout the course. You will be given study assignments to complete outside classroom periods.

Workbooks

These contain work projects which you will complete in the classroom or in training areas where the equipment is located.

Programmed Instruction Packages/Texts

These books are a totally new and scientific approach to learning. Programmed Instruction Packages (PIPs) are a combination of study guides and workbooks which require student response throughout. We think you will enjoy this new way of learning.

Study guide/workbook is a combination study guide workbook which will be used to administer the directed study in this course.

STUDENT PROGRESS POLICIES

The course is based on a series of criterion objectives. Each criterion objective is satisfied by completing a series of teaching steps. A brief explanation of criterion objectives and teaching steps follows:

Criterion Objectives

A criterion objective is defined as, "The specification of the behavior which leads to or satisfies a job performance requirement or standard." Simply stated, for each element of training which you must successfully accomplish in this course, there will be a criterion objective. You must accomplish all of these criterion objectives. The instructor or supervisor will certify your accomplishment of criterion objectives on a Criterion Checklist as you progress through the course. This is a Progress Check. He or she must document all criterion objectives as being satisfactorily attained prior to administering a measurement test at the established test point. You cannot be administered a measurement test for advancement to the next block or unit of instruction until you have accomplished all the criterion objectives for the unit in which you are assigned. Additional instruction will be provided if you need it; hard work and study on your part are very important.

Measurement Tests

The Measurement Test is an objective type written test designed to measure knowledge as applied to special tasks. It is used to provide a permanent record of your progress and achievement in the course. The measurement tests you are administered may contain from 25 to 50 individual test items, usually in multiple-choice form. Remember, your accomplishment of these measurement tests will go on your permanent course attendance record. Do the very best you can to make good grades. It is well worth the effort.

Written instructions will be furnished you at the beginning of each test period. Read these instructions carefully, they affect YOUR future.

Questions missed on each test will be reviewed (critiqued) by the instructor and class to help you identify mistakes you made during testing. During these critiques, you will not be permitted to make notes as the rules for protection of measurement tests are very strict. You will be informed of your test scores as soon as possible after the test period. You probably won't fail any tests, but if you should, you will be given additional instruction and will be retested, or washed-back to repeat the unit of instruction.

Special Individualized Assistance

Remedial instruction is provided to give extra help to students in learning course material. If instruction on a particular subject isn't clear, you may voluntarily ask your instructor to be placed on remedial instruction. Remedial instruction may also be compulsory should you have failing daily quiz scores or if your instructor thinks you need extra study.

When attending remedial study, your instructor will give you two special study assignment forms. A copy of the special study form is presented to your squadron training NCO. The original is kept by you and given to your instructor when remedial instruction is completed.

The classroom instructor will inform you of the time, dates, and location of your remedial instruction. You will be assisted during this study time by an instructor, or instructors so as to improve your daily quiz scores and block grades.

Proficiency Advancement

This is a program to allow you to be tested on any portion of the course in which you have already had training or experience. In other words, it isn't economically sound to take up your time training you in a subject in which you are already proficient. If you should identify a block in the course which contains material for which you have had good training and for which you feel you can pass the tests, you should apply for proficiency advancement. If you pass all the required tests, you can bypass these materials and graduate ahead of your class.

School Grading

The two types of measurement you will be subjected to are the Criterion Progress Check and the Measurement Test. Since you must complete all criterion objectives for a unit of instruction prior to being administered the measurement test, the instructor will perform a continuing assessment of your progress in accomplishing the criterion objectives. He or she will observe your performance activities, insure that you complete all workbooks, and may give you short written quizzes to satisfy him or herself that you have accomplished each criterion objective. Upon the instructor's satisfaction with the results of these criterion progress checks, he or she will certify on the criterion checklist that you have accomplished the criterion objective in question. When you have completed all criterion objectives in a given unit or block of instruction, he or she will certify that you are ready for the measurement test.

If you should fail a test, the instructor or supervisor will discuss the failure with you and will counsel you on the best action to take. During these counseling sessions, remember that the instructor or supervisor is interested in your problems. He or she has nothing against you and is only trying to arrive at the solution to whatever the problem was that caused you to fail. Be honest with him or her and discuss your problems. The discussion will benefit both of you.

Once you fail a test, three avenues are open: probationary continuation, washback, or elimination. If you, the instructor, and the supervisor feel that you are able to accomplish the materials in which you failed and at the same time acquire the materials in the next block, the instructor will recommend you for the probationary continuation. During this probationary period, you will be given remedial (extra) instruction outside of normal class hours. Upon completion of the periods of remedial instruction, you will be retested and if you pass you will continue in the new block.

If you should fail your retest, the second option of washback will most likely be used. In this case, you will be washed-back to a class behind you to repeat the block in which you failed to make passing grades. Upon failing to pass the test after repeating a block, or upon one or more washbacks, you may be considered for elimination in your best interest or in the best interest of the Air Force. Remedial instruction is available to help you avoid the possibility of washback or elimination.

STUDENT RECOGNITION PROGRAM

The honor graduate is a program designed to reward those students who have demonstrated outstanding academic performance. In short, it is a program which allows for special recognition of those students who really apply themselves to acquiring as much benefit as possible from technical training.

The program provides that approximately the top 10 percent of graduates from a course in a year will be designated as Honor graduates. To qualify for the Honor graduate award you must of course complete the course with a high average course grade. In addition, you must have maintained an excellent record of conduct in both the school and the squadron. Students who have washed back, or who have been allowed to continue on a probationary basis, due to academic deficiencies, are not eligible to compete for Honor graduate. Also, personnel who violate the established rules of good conduct will not be considered.

Those students who earn the Honor Graduate designation are awarded a Honor Graduate Certificate. This special recognition certificate is signed by both the Group Commander and the School Commander. It is a certificate you will be proud to receive since it will reflect your very own efforts. While the instructors are required to provide you the best possible instruction, the grades required to become a Honor Graduate can only be achieved by you. Your efforts alone are rewarded when you are designated a Honor Graduate. The certificate will be a visible recognition of the high performance standards you have maintained; however, your extra efforts in accomplishing the course objectives to the very best of your ability will also result in your being a better trained specialist. These extra efforts will serve you well during your tour or career in the Air Force, and throughout the rest of your life. Do your best to maintain the very highest of performance standards. Do this for us and also for you.

EFFECTIVE STUDY TECHNIQUES

Study Skills

A great amount of study is required to complete any course with a good understanding of its content. This is usually a problem for many of us since we really don't know how to study effectively. To help you overcome this drawback, a copy of Air Training Command programmed text will be furnished to you. This programmed text, ATC Programmed Text 52-11, Study Skills, must be completed by you. It will do you more good than you can possibly imagine, so be sure you complete it as assigned by the instructor. Also have your instructor check it for correct completion.

PROCEDURES FOR SHELTER EXERCISES AND FIRE EVACUATION PLAN

Fire evacuation plans and alert procedures are posted in each classroom on the bulletin board. The instructor will brief you on evacuation procedures and reassembly location.

The instructor will also brief you on the alert signals used in storm warnings and for drills required by simulated or actual attacks by enemy forces. He or she will inform you of the actual location of your designated fallout shelter and the evacuation procedures to be used. To reinforce what he or she tells you, locate alert warning procedures on your school and squadron bulletin boards and become familiar with the required procedures. Do this before you need to use the procedures. While we are face to face with a Texas tornado or an enemy attack is a poor time to have to study the fine print. Be prepared.

STUDENT CRITIQUE PROGRAM AND IT'S OBJECTIVE

Air Training Command regulation (ATCR) 52-29, Student Critique Program, provides the guidance and instructions for administering this program.

The regulation lists the objective of this program as, "The student critique program was established to obtain from students constructive criticism of training, the training environment, and base support facilities and services."

You can see why a program of this type is necessary. We, who work in the school day in and day out, know how the school looks to us. Unless you tell us on your critique form we will not know how it looks to you. The overall policies for the critique program are generally as follows:

- _____ You are required to be briefed on the critique program. This study guide will provide some of this briefing.
- _____ You will receive specific instructions upon being presented the end of the course critique forms. Generally, critiques are submitted by you on graduation day; however, you may submit one any time you identify a need to do so.
- _____ You do not absolutely have to identify yourself on the critique form, but you are encouraged to do so. You can submit a signed critique without fear of prejudice or reprisal. We are interested in obtaining your constructive comments, don't hesitate to put them down and put your name on the form.
- _____ You may make changes to your critique form before you submit it; however, no alterations may be made after you submit it.
- _____ Your comments are not disclosed to other students. They are entitled to their judgments of the course as well as you.
- _____ Your critiques are reviewed by personnel responsible for all aspects of the training program. Often we find that students identify things which we may have overlooked.

Your critique of the school and training program will include your appraisal as to the effectiveness of: Instruction, Individual Assistance, Training Methods, Training Literature, Visual Aids, Training Equipment, Written and Practical Tests, Classroom and Training Area, and an Overall Evaluation of the Course. To make sure you are in a position to make worthwhile comments to these elements of the training program, you may want to keep notes at the end of each block. If you keep notes from every block of instruction, you can simply review your notes and complete the end-of-course critique. Remember, we are concerned with constructive comments which can be used to improve training.

In addition to the training critiques, you will also complete a form dealing with base facilities and services. The base commander reviews these for ideas in improving the base services. This critique will cover such items as Dining Hall, Club, Recreation, Base Services, Security Police, Base Transportation, Mail, Administration (pay, etc.), Medical, and again an Overall Evaluation.

So, once again keep in the notes you need as you go through our course and at the end give us a critique which will be of assistance in improving the training for others who come after you are gone. We will appreciate your help.

CONSERVATION

You will be required to be very saving with the training material, training equipment and other resources. In this time of high prices and short money, waste cannot be tolerated at any level. If you see an area where waste is occurring, notify your instructor or instructor supervisor immediately.

DISPOSITION OF ELIMINEES

Elimination is one aspect of your Air Force experience that we don't like to think about. Most of us have a strong desire to successfully complete any undertaking we begin. The same way with the course in which you have been enrolled. It is of course to your very best interest to work as hard as you can to complete the course. It should become a matter of pride to be successful in your undertaking.

If you should fail, after all the efforts you and the instructors put forth, you would most likely be reassigned to a career field with lower entrance requirements and one which is less technical. Also you probably would not get a chance to attend the technical school for that career specialty. You most likely would receive a direct duty assignment to the field to learn the specialty by on-the-job training (OJT). All this is, of course, if you fail the course you are now in through no fault of your own.

If you should fail and the elimination board determined it to be your fault by your not applying yourself or by other unsatisfactory action on your part, you could receive disciplinary action. As we said before, this is an aspect we don't like to talk about, so just apply yourself and don't fail.

TDY PERSONNEL PROCESSING

The instructor will provide the specific procedure for TDY personnel to process in and out of the base.

SUMMARY:

It has been our aim in this study guide to tell you a little about our school. We hope we have made a good impression on you and hope that you can understand the importance of your position in the Air Force.

REFERENCES

1. Programmed Text - 2TPT-9039-01, Civil Engineer Mechanical/Electrical Career Field.
2. ATC Programmed Text 52-11, Study Skills.
3. ATC Regulation 52-3, Student Measurement.
4. ATC Regulation 52-29, Student Critique Program.
5. 3700 TCHTW Regulation 50-30, Student Orientation and Motivational Procedures.

CIVIL ENGINEERING ORGANIZATION AND SAFETY

OBJECTIVE

This portion of the study guide-workbook will introduce you to the mechanical/electrical career field, progression in your career ladder, and duties of your AFSC's skill level. You will become acquainted with the AF Occupational Safety and Health (AFOSH) program, and you will be presented with some first aid procedures you may need during the course of your work in Refrigeration and Cryogenics.

INTRODUCTION

Materials presented in this section will cover the following topics:

- o Civil Engineering Mission and Organization
- o Mechanical/electrical Career Field
- o Progression in Career Ladder
- o Duties of the AFSC's Skill Level
- o AFOSH Standards for AFSC 545XO
- o Hazards of AFSC 545XO
- o Occupational Health Training
- o Hazard Reporting and Abatement
- o Mishap reporting and Investigation
- o Individual Responsibilities to the AFOSH Program
- o First Aid Procedures for:
 - Electrical shock
 - Controlling bleeding
 - Traumatic shock
 - Heat exhaustion and heat stroke

CIVIL ENGINEERING MISSION AND ORGANIZATION

The primary mission of civil engineering activities is to acquire, construct and maintain and operate real property facilities, and provide related management, engineering and other support work and services.

Organizational Structure

Base civil engineering responsibilities are specifically spelled out by Air Force regulations, but major commands are authorized to make minor changes in the organizational structure to fit the needs of a particular base. Figure 1 illustrates the organizational structure of a base civil engineering unit.

The organization is headed by an officer, usually a professional engineer, who is designated as the base civil engineer. The BCE is responsible for the overall planning, directing, supervising and coordinating of all civil engineering activities on the base to which he or she is assigned. Next in line is the deputy BCE, who may be either a military officer or a civilian.

The BCE organization is divided into six divisions and the squadron section. The squadron section and each of the main divisions--financial management, industrial engineering, family housing management, operations, engineering and environmental planning, and fire protection--are directly subordinate to the BCE. The divisions are subdivided into branches and individual shops.

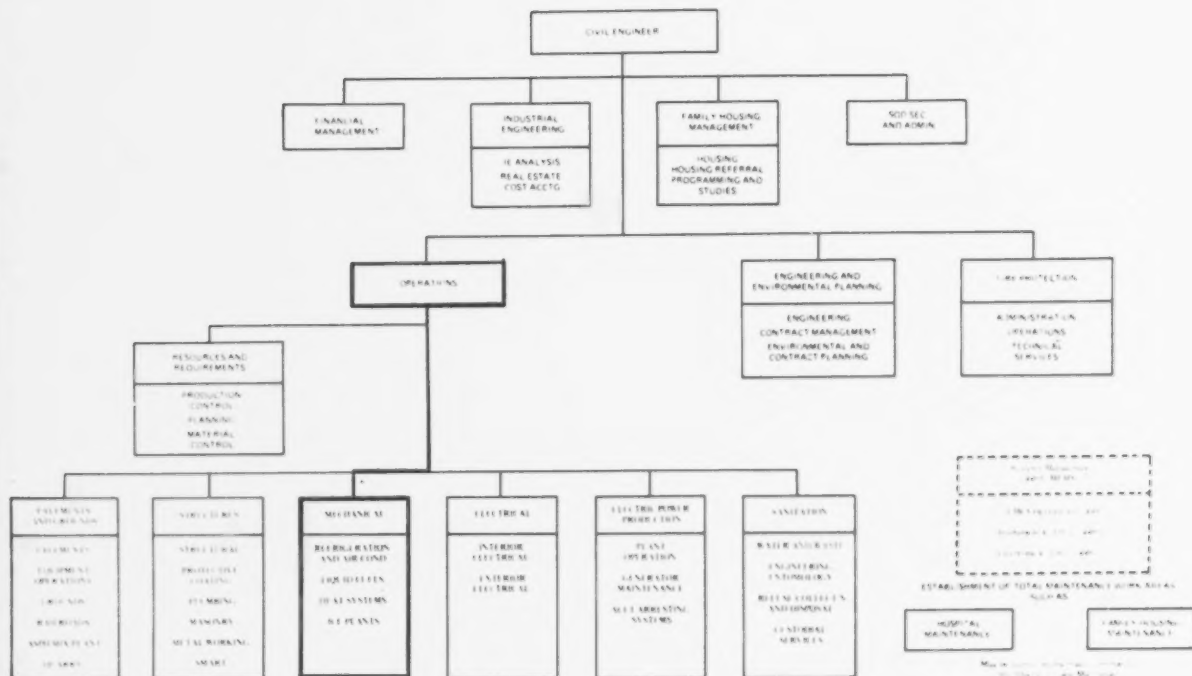


FIGURE 1, BASE CIVIL ENGINEER ORGANIZATION CHART

CAREER FIELD

To effectively accomplish the mission of national defense, the Air Force has grouped the many jobs and duties involved into many different career fields. Some of these career fields, or personnel in some of these career fields, take care of food service activities, pay, transportation, personnel records, aircraft maintenance, communications, and many other functions necessary to USAF mission accomplishment.

You have been assigned into one of the career fields which support Air Force civil engineering activities. Air Force civil engineering has the responsibilities for the procurement, operation, and maintenance of base property in general. This property includes land (grounds); roads, buildings, water supply, sewage, electrical, air-conditioning and heating systems, air field runways and runway lighting systems, and to make it a safe, healthful place to work. The three career fields which are regarded as civil engineering career fields are the mechanical/electrical (one you are in) the construction, and the sanitation career fields.

Mechanical/Electrical Career Field (54)

This career field in which you are now assigned includes the specialties responsible for the installation and maintenance of equipment and systems which are considered to be primarily electrical and mechanical. The specialties within this field include electrician, electric powerline, electrical power production, refrigeration and cryogenics (yours), liquid fuels, heating, and CE controls systems. The 54 career field is by far one of the more interesting career fields in which to be assigned.

The above general summary of civil engineering career fields has been given so that you will have knowledge of other specialties in civil engineering. The details of your very own career field will be provided you in a programmed text. You will be issued this programmed text--2TPT-9039-01, Civil Engineering Mechanical/Electrical Career Field (54), for your completion. Be sure you complete it and have your instructor check it for correctness. Your success in any field of accomplishment depends upon your understanding of what that field consists of. The programmed text also outlines the skill levels and grades you will attain as you progress in your career field; however, we need to go into some further details of your very own career specialty and the actual mechanics of the Air Force career progression program.

Refrigeration and Cryogenics Specialty

This specialty in which you are assigned is one ladder of the 54 career field as you will discover when you accomplish the programmed text. Your specialty requires you to be proficient in the installation, modification, operation, and maintenance of refrigeration and cryogenics systems and components. The details of the knowledges and skills required are contained in a specialty summary contained in Air Force Regulation 39-1, Airman Classification Regulation. A copy of the specialty summary is included here so that you will understand the full scope of your specialty. You will note that the specialty summary is for both the 3- and 5-skill levels. You will serve as an apprentice in these jobs as a 3 level, then do the entire job yourself when you reach the 5 level. As a 5-level specialist, you will also be responsible for assisting new 3-level personnel, those who come along after you. Help them as much as you can, remembering all the people who helped you. Study the following specialty summary carefully. It reflects your job for the next several years: A Very Interesting and Important Job.

AIRMAN AIR FORCE SPECIALTY
REFRIGERATION AND CRYOGENICS SPECIALIST

*1. SPECIALTY SUMMARY

Installs, operates, maintains, modifies, and repairs refrigeration, all types of air conditioning, cryogenic fluid production, storage tanks at production facilities, evaporative cooling, air compressing, and ventilation equipment, plants, and systems, including portable units other than Aerospace Ground Equipment (AGE).

*2. DUTIES AND RESPONSIBILITIES

a. Installs refrigeration, air conditioning, ventilation, air handling and cryogenic fluid production systems and related control systems and equipment. Aligns, adjusts and services components and equipment such as compressors; condensers; electric motors; gasoline and diesel engines; centrifugal refrigerating machines; steam and gas absorption refrigeration plants, heat exchangers; heat pumps; expanders; evaporators; regulators; fans; pumps; tubing; ducts; electrical wiring harnesses; sensing and switching devices of direct and indirect expansion systems; and cryogenic fluids production systems. Shapes, sizes, and connects tubing and components, using special bending, flaring, and coupling tools and oxyacetylene torches for soldering and brazing. Connects and adjusts refrigeration and cryogenic fluids production equipment to source of power. Conducts tests of installed equipment for proper assembly of components and compliance with technical orders, manufacturer's handbooks, and local procedures.

b. Operates and maintains refrigeration, air conditioning, ventilation, cryogenic fluids production, and storage tanks at production facilities and related control systems, and cryogenic plants and associated equipment for production of gaseous and liquid nitrogen. Actuates mechanical and electrical controls to start and adjust output of power source engines and motors and place systems in operation. Observes and interprets temperature and pressure gauges and recorders. Adjusts manual and automatic controls to produce required refrigeration and/or flow of refrigeration or cryogenic fluids. Services components such as electric motors, compressors, valves, and moving mechanical parts with appropriate lubrication. Disassembles, cleans, and reassembles such components as ruptured disks; safety valves; automatic valves; hand-operated valves; air compressor valves; pistons; bearings; cylinder heads; connecting rods; pumps; pressure gauges; liquid level gauges; heater elements; and moisture, oil, and sedimentation traps, filters, and strainer assemblies. Performs preventive maintenance of systems components. Detects scale and corrosion by making tests for pH, phosphates, and total dissolved solids and applies preventive treatment. Applies precautionary procedures required in handling refrigerant gases and cryogenic fluids and associated chemicals and in maintaining high pressure lines and components. Defrosts, performs blow downs, and sets cryogenic plant valves for storage. Cleans, dries, purges, and degreases charging lines, charging manifolds, storage cylinders and tanks, filling hoses, tank connections, and all other cryogenic equipment to insure removal of combustible materials. Charges and stores cylinders and storage tanks with gaseous products and/or cryogenic fluids. Maintains inspection and maintenance records. Records gauge readings and other pertinent data in equipment performance logs. Furnishes information required for unsatisfactory reports and recommends changes to correct defective equipment or to improve operating procedures.

c. Identifies problems and troubleshoots refrigeration, all types of air conditioning, and cryogenic fluids production and associated equipment. Mixes solutions and maintains quality control of oxygen and nitrogen products. Analyzes and isolates systems malfunctions. Tests pressure and temperature of refrigeration and distribution systems, using pressure gauges, recorders and thermometers. Analyze pressure-temperature relationship; determines presence of noncondensable gases and removes by purging or

evacuating. Tests systems operation and purity and purging or evacuating. Tests systems operation and purity and detects component malfunctions using test equipment. Isolates electrical malfunctions by use of test equipment. Removes, repairs, and/or replaces systems components or component parts. Performs operator and minor maintenance on engines and electric motors. Solders joints and repacks or replaces valves. Cleans, dries, purges, and recharges components and lines with appropriate refrigerants and fluids. Checks installed safety devices for operation. Performs inspections and purity control measures as required by applicable technical orders.

d. Maintains tools and equipment. Cleans and uses common tools, special tools, and testing devices used in analysis and maintenance of refrigeration and cryogenic fluids production systems.

e. Supervises refrigeration, air conditioning, and cryogenic fluids production personnel. Conducts on-the-job training. Assigns work and reviews completed repairs for compliance with local procedures, safety procedures and applicable technical publications. Instructs subordinates in techniques and procedures for functions such as installation, operation, inspection, maintenance handling, storage, and repair of refrigeration, air conditioning, and cryogenic fluid production equipment and cooling systems and equipment. Arranges for placement of materials and directs work when serving as crew/shift leader. Evaluates work performed and informs immediate supervisor of status of projects.

3. SPECIALTY QUALIFICATIONS

a. KNOWLEDGE. Knowledge of principles of refrigeration, thermodynamics, psychrometrics, and mathematics that apply to refrigeration; principles of chemistry and physics that apply to oxygen/nitrogen production; characteristics, chemical properties, and use of refrigerants; techniques of installation, plant operation, maintenance, and automation of refrigeration, air conditioning, and equipment cooling and heating systems; nomenclature, types, and sizes of refrigeration and air conditioning systems and equipment; associated electrical materials such as wire, fuses, and cables; interpretation of schematic and wiring diagrams, blueprints, and technical publications; and safety codes, practices, and fundamentals of oxygen/nitrogen plants and procedures is mandatory. Possession of mandatory knowledge will be determined according to AFR 35-1.

b. EDUCATION: Completion of high school with courses in general science, mathematics, physics, and shop mechanics is desirable.

c. EXPERIENCE. Experience in functions such as installing, operating, maintaining, and repairing refrigeration or environmental control equipment; plant operation; or in cryogenic fluid production is mandatory.

d. TRAINING. Completion of a basic refrigeration/air conditioning course or a cryogenic fluid production course is desirable. Completion of a cryogenic fluid production course is mandatory prior to assignment to a cryogenic fluid production facility.

e. OTHER:

- (1) A minimum aptitude level of Electronic 50 or Mechanical 50 is mandatory.
- (2) Physical qualification for military drivers according to AFR 160-43 is mandatory for entry into this AFSC.
- (3) A minimum of Grade 1 color vision as defined in AFM 160-17 is mandatory.

AFOSH STANDARDS FOR AFSC 545XO

Background Information

Executive order 11807, Occupational Safety and Health Programs for Federal Employees, tasks each federal agency to establish procedures for the adoption of occupational safety and health standards. AFR 127-12 includes overall policy and procedures for implementation of the act.

Air Force Occupational Safety and Health (AFOSH) Standard is defined as a special Air Force publication which prescribes conditions and/or methods necessary to provide a safe and healthful work environment in AFSC 545XO.

AFOSH standards are published as specialized publications. These standards are issued for maintenance in two volumes. Volume I will contain standards which primarily concern occupational safety. Volume II will contain standards that primarily concern occupational health.

Read the following paragraphs, and be prepared to discuss them in class.

While working as a Refrigeration and Cryogenics Specialist, you will find this field to be interesting and rewarding. There are certain hazards inherent with this career field that, if caution and responsible work habits are not observed, could cause injury, and possibly death. These hazards include, but are not limited to the following:

- o Electric shock
- o High pressure refrigerant lines and cylinders
- o Drive belts
- o Phosgene gas
- o Liquid refrigerant
- o Fans
- o Heavy equipment

Electric Shock

Trouble shooting a refrigeration or airconditioning system is one of the many jobs you will encounter, and one that you will spend a considerable amount of time doing. If possible, your first action of troubleshooting an electrical circuit should be to shutoff the power. Just shutting off the power, and then going to work will not adequately protect you. While you are busy troubleshooting the unit, taking wires off, and putting wires back together, what is to stop someone from noticing that the system is not operating, and from noticing that the power switch is turned OFF, and from turning it back on suddenly making the circuit you are working on hot? To prevent this from happening to you, always hang a tag or a note on the power switch saying that you turned it OFF and that you are working on the circuit.

Even when the circuit has been turned OFF and tagged, an apparently dead electric circuit can still be energized by what is known as feedback. Electrical feedback is when parts of an open circuit remain energized from a connecting circuit that has not been opened. Always check an open circuit with a voltmeter to be sure it is not energized.

High Pressure Refrigerant Lines and Cylinders

Some of the systems you will be working with operate at very high pressures. Refrigerant lines could be holding pressures close to 400 PSIG. Nitrogen lines (Cryogenics) could hold pressures near 3500 PSIG. Be sure to reduce line pressures to a safe level before working them.

Pressurized cylinders, such as refrigerant cylinders could become very dangerous if not handled carefully. If the valve is somehow knocked off the cylinder, possibly by dropping it, the cylinder could turn into a pressurized missile, causing destruction and injury to anything or anybody in its path. Never heat a pressurized cylinder with a torch. To do so could cause excessive pressure to build up inside the cylinder causing a violent explosion.

Drive Belts

Much of the machinery you will work with will use drive belts to drive fans, compressors, and other uses. These drive belts, while operating, are capable of drawing loose clothing, or parts of your body into the pulleys, causing extreme injury, amputation, or even death.

Phosgene Gas

Normally halogen refrigerants are non-toxic, although the vapor will displace the oxygen in a closed environment causing suffocation. When halogen refrigerant vapors come in contact with an open flame, they form a poisonous gas called Phosgene.

Phosgene gas is used as a chemical warfare agent. Exposure to phosgene gas can make you very sick. Any time you are applying heat to any part of a refrigeration system, and the environment contains refrigerant vapor, be sure the area is well ventilated.

Liquid Refrigerant

Most of the refrigerants that you will be working with have very low boiling temperatures. R-12 boils at -22°F , R-22 has a boiling temperature of -41°F and R-502 boils at -50°F . (All boiling temperatures are at atmospheric pressure). While liquid refrigerant is boiling, it is absorbing heat, and making the surface it is boiling on very cold. If the surface the liquid refrigerant is boiling away on happens to be your skin, it could cause frostbite (Freezing a part of the body). If liquid refrigerant happens to get in your eye, it could cause blindness. Always wear safety goggles when working with refrigerants.

Fans

Refrigeration condensing units may be water cooled or air cooled. If the units are air cooled, they require a fan. Some of the fan blades may be quite large physically, and they rotate at a high rate of speed. Carelessness or loss of concentration around an operating fan could cause you to stick a finger or hand into the rapidly rotating fan blade causing a serious traumatic injury.

Heavy Equipment

Occasionally your job will call for you to move or lift heavy pieces of equipment such as electric motors, large refrigerant cylinders, compressors, and many more. Failure to lift properly, or to get enough help to lift could cause injury to your back or other muscles of your body. If a large piece of equipment should be dropped on part of you, that part could be extensively injured. Be sure heavy items are well secured after setting in place so they won't fall or roll.

High Intensity Noise

During the course of your duties, you may be working in an area that contains machinery that operates with a noise level that your ears cannot tolerate. Exposure to this high noise level for an extended period of time can lead to loss of hearing if appropriate measures are not taken. Wear ear protection devices such as ear muffs or ear plugs when working in a known high intensity noise area. There are other areas of this career field that could produce hazardous conditions if you are not wisely cautious with your working habits.

Read the following paragraph and be prepared to discuss them in class.

Occupational Health Training

Supervisors will give occupational health training to each newly assigned worker and each worker who has not previously received this training. Additional training will be given if required by a change in assignment, equipment, procedures, processes, or standards. Occupational health training will be of sufficient length and depth to ensure that workers know:

- o Hazards of the job tasks they will do
- o Hazards of the work areas
- o AFOSH standards and other AFOSH guidance that apply to their job and workplace
- o Personal protective equipment they will need and how to use it
- o Location and use of emergency and fire protection equipment
- o Emergency procedures that apply to their job and workplace
- o How to identify and report hazards
- o How to repeat work-related injuries and illnesses

Read the following paragraphs and be prepared to discuss them in class.

Hazard Reporting and Abatement

Mishap prevention depends on early identification, reporting, and correction of hazards. A hazard may be reported by any person, military or civilian, assigned or attached to the Air Force, or under contract to the Air Force. A hazard is defined as any existing or potential condition, act, or procedure that can result in a mishap.

Report hazards first to the supervisor or local agency so that action can be taken. If the hazard is eliminated on the spot, no further action is required unless it applies to other similar operations or to other units or agencies. Reports may be submitted anonymously. If the response to a hazard is not satisfactory, the originator should contact the Chief of Safety.

Hazard abatement is defined as the elimination or permanent reduction of a safety, fire, or occupational health deficiency by coming into compliance with the applicable AFOSH standard or other safety or health guidance. The safety staff plays a key role in the hazard abatement program. They evaluate each report, assign a risk assessment code, send the report to the appropriate functional manager for action, give technical expertise, and monitor corrective action. The functional manager will take action to correct the hazard, and keep the safety staff advised of the status of corrective actions. The functional manager must also make sure personnel are not exposed to undue risk during the time required to take action. Where possible, hazards are corrected through engineering changes to equipment, changes to procedures, or administrative controls.

Read the following paragraphs and be prepared to discuss them in class.

Mishap reporting and investigation

AFR 127-4 sets up the program for investigating and reporting US Air Force mishaps. Air Force mishaps are investigated to find their causes and take preventive actions. Air Force mishaps are reported to all levels of command and to certain other action agencies.

Air Force mishap is defined as an unplanned and unsought event not caused by combat, which:

- o Results in injury to air Force military and civilian personnel
- o Occupational illness in military or civilian Air Force personnel.
- o Damage to Air Force property or equipment
- o Damage to non Air Force property as a result of Air Force operations
- o High accident potential, even though it did not result in injury, occupational illness, or reportable damage.

Read the following paragraphs and be prepared to discuss them in class

Individual responsibilities to the AFOSH program

All air force employees, civilian or military, are charged with certain responsibilities concerning the AFOSH program. They are as follows:

- o Comply with AFOSH standards and other AFOSH guidance
- o Promptly report safety, fire, and health hazards
- o Promptly report occupational injuries and illnesses to supervisor
- o Wear or use required protective clothing or equipment
- o Take care while doing assigned tasks. Give due consideration to personal safety and the safety of fellow employees.

SAFETY

Directed Study assignment in preparation for Day 2 instruction.

Read the following paragraphs and answer the questions as indicated.

FIRST AID

Some day you may save someone's life, possibly your own, if you know how to properly render first aid. As you know, first aid refers to the treatment given the sick or injured before regular medical or surgical treatment can be administered by trained personnel.

1. What is first aid? _____
- _____
- _____
- _____
- _____
- _____
- _____
- _____
- _____
- _____

ELECTRICAL HAZARDS AND SAFETY PRACTICES

Almost everyone is required to work on or around electrical circuits as they do their job in the Air Force. You cannot see electricity; therefore, you cannot determine by looking at a conductor if it is energized by voltage. Also, you cannot determine the amount of voltage applied to the conductor. In order to work safely around electrical equipment, you must understand the following:

- * Operation principles of ac and dc electricity.
 - * Functions of the electrical circuits you maintain.
 - * Use of electrical safety equipment.
 - * Safety precautions to be observed.
 - * Conditions which cause an electrical shock.
 - * Effects of an electric shock.
 - o Can you tell by looking at it if a conductor (wire) is energized or not? _____
 - o List four things you must understand to work safely around electrical equipment.
-
-
-
-

A number of people are electrocuted each year because they fail to understand one or more of the above items. For example, when a person is electrocuted, death resulted from which of the following?

- * Voltage
- * Current
- * Resistance

An electrical shock includes all three of these factors. However, "current" is the "killer" in the case of electrical shock.

Voltage is an electrical pressure which causes tiny electrically charged particles (electrons) to flow through a conductive material.

Current is the movement of these tiny electrically charged particles (electrons) through the conductive material. Movement of electrons through the human body affects the muscles and nervous system. When the current exceeds a certain value, the muscles affected become paralyzed. This causes the heart to stop beating and the lungs to stop functioning. If this condition prevails long enough, death results.

Resistance is the factor which opposes the flow of current. The amount of resistance that the human body has depends on certain conditions. The skin, when dry, has a high resistance. This skin characteristically acts to protect a person from electrical shocks by low voltages. However, when the skin is wet or damp, it has a smaller amount of resistance. Therefore, a person whose skin is wet may be electrocuted by low voltage (about 100 volts), while a person with dry skin may not be electrocuted with voltages of this low value.

- o What is the "Killer" in the case of electrical shock? _____
- o What causes electrons to flow through a conductive material? _____
- o Movement of electrons through the human body affects the _____ and _____.

- o. When the skin becomes wet or damp what happens to the resistance? _____

Effects of Electric Shock

Electric shock may cause instant death or unconsciousness, cessation of breathing, and burns of all degrees. If a 60-cycle alternating current is passed through a person from hand to hand, or from hand to foot, the effects when current is gradually increased from zero are as follows:

- * At about 1 milliamper (0.001 ampere) a slight shock can be felt.
- * At about 10 milliamper (0.010 ampere) the shock is severe enough to paralyze muscles so that a person may be unable to release the conductor.
- * At about 100 milliamper (0.100 ampere) the shock is fatal if it lasts for one second or more.

Almost all electrical injuries are caused by carelessness or overconfidence in handling equipment. Most personnel are likely to think in terms of high voltages, but death lies in the low voltages too. The following facts are presented to illustrate the hazards of low voltage.

The human skin, through its resistance, acts as a protector against electrical shock. This resistance to electrical current varies between 100,000 and 600,000 ohms for dry skin. It may be as low as 1000 ohms for wet skin. The resistance of the internal body, hand to foot, is about 400 to 600 ohms, and from ear to ear, 100 ohms.

Assume that 120 volts is applied to the perspiring skin of a worker who is standing on a good electrical ground. Further assuming the worker has a total resistance of 1500 ohms, the current through him or her would be about 0.08 ampere or 80 milliamperes. This amount of current is not always fatal, but it is painful. It causes severe muscular contractions and makes breathing difficult. If the current absorbed is between 100 and 200 milliamperes, it produces a heart condition, wherein the heart muscle fibers work independently and without rhythm, causing instant death.

- o What could electric shock cause? _____
- o At about _____ a shock is fatal if it last for one second or more.
- o Almost all electrical injuries are caused by what? _____

- o The _____ acts as a protector against electrical shock.

Treatment for Electrical Shock

Immediate action must be taken in cases of electric shock. Seconds count as they can mean the difference between death and recovery. Artificial respiration is the fundamental first aid measure for this emergency. A person coming in contact with a "live wire" is the usual cause of electrical shock. If the switch is nearby, turn it off, but do not spend time hunting for the switch. Remove the victim from the wire by using a dry wooden pole, dry clothing, rope, or any nonconductor. Be sure not to touch the wire or victim with your bare hands or you will end up in the same condition as the victim. Artificial respiration should be started immediately after freeing the victim from the wire.

- o What is the fundamental first aid measure for electrical shock? _____

- o How would you remove a victim from a live wire? _____

HEART-LUNG RESUSCITATION

Resuscitation procedures described herein are in two parts: which, when combined, constitute heart-lung resuscitation. These procedures are applicable to victims of electrical shock, heart failure, drowning, suffocation, and certain other causes; however, the original consideration here is electrical shock.

Artificial respiration is applicable where respiration has stopped, but there is a pulse however slight. The easiest place to detect the pulse is not in the wrist, but in the throat on either side of the windpipe near the collarbone. In cases where no pulse is apparent, use closed chest cardiac massage along with artificial respiration.

Closed chest cardiac (heart) massage is the rhythmical compression of the heart without opening the chest by surgery. It is designed to provide an artificial circulation in order to keep blood flowing to the brain and other organs until the heartbeat has been reestablished. Closed chest cardiac massage is used in cases where the heart has stopped beating (cannot detect a pulse).

The primary reason for the heart's ceasing to beat is insufficient oxygen to the vital centers. This could result from smothering. Other reasons include electrical shock, excessive bleeding, shock, heart disease, effects of certain drugs, and even anxiety.

When the heart stops beating or breathing stops, it is always an emergency. Be calm; think; act! Time is of the utmost importance - SECONDS COUNT! If you are alone, or there are only two of you to conduct emergency aid, DO NOT TAKE THE TIME TO SEND FOR HELP. If additional personnel arrive, then send for medical personnel. The great danger when the heart or breathing stops, is the lack of sufficient oxygen carried in the blood to feed the brain. The brain is the most sensitive tissue of the body and the results of a shortage of oxygen becomes severe within a few minutes (usually about three) after breathing and circulation are cut off. Thus, while a victim who has had delayed resuscitation may live, he or she faces the possibility of extensive brain damage - a human vegetable.

- o Where is the easiest place to detect a pulse? _____

- o If there is no pulse what should you do? _____

- o What is the danger when the heart or breathing stops? _____

Mouth-to-Mouth Method

This method of artificial respiration is accomplished by executing the procedure listed below.

1. Place the casualty on his or her back (face up). Do not put anything under the head as it may flex the neck, causing the air passages to be blocked.
2. After turning the victim's head to the side, quickly clear the mouth of any foreign matter by running your fingers behind his or her lower teeth and over the back of the tongue. Wipe out any fluid, vomitus, or mucus. This cleaning should not take more than a second or two since little time should be lost in getting air into the casualty's lungs.
3. If available (do not waste time looking for these materials) place a rolled blanket or some other similar material under the shoulders so that the head will drop backward. Placing one hand under the victim's neck, and the other hand on his or her forehead, tilt the head back so that the neck is stretched and the head is in the "chin-up" position, see Figure 2. This aligns the air passages so that they do not become blocked by kinking or pressure. Using the hand on the patient's forehead, pinch the nose shut in order to prevent air leakage.



Figure 2

o When preparing a victim for mouth-to-mouth resuscitation, why would you not place anything under the victim's head? _____

o Why must you pinch the nose shut when giving mouth to mouth resuscitation? _____

4. Take a deep breath and open your mouth wide. Seal your mouth around the casualty's mouth and blow forcefully (except for infants and small children) into his or her mouth until you see the chest rise, see Figure 3. If the chest does not rise check to make sure the victim's neck is hyper-extended and try again while making sure there is no air leakage around the mouth or nose.

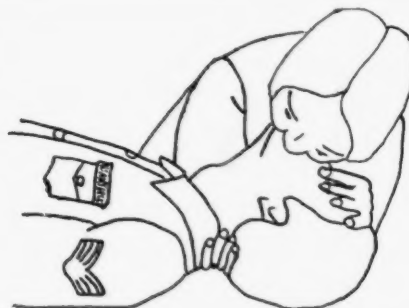


Figure 3. Apply Mouth-to-Mouth Respiration

5. When the victim's chest rises, stop blowing and quickly remove your mouth from his or hers. Take another deep breath while listening for his or her exhalation.
6. When exhalation is finished, blow in the next deep breath. The first five to ten breaths must be deep (except for infants and small children) and given at a rapid rate in order to provide rapid reoxygenation. Thereafter, continue breathing at a rate of 12 to 20 times a minute.

CAUTION: Excessively deep and rapid breathing may cause you to become faint, to tingle, and even to lose consciousness. Therefore, after the first five to ten breaths, adjust your breathing to a rate of 12 to 20 times a minute with only moderate increase in normal volume. In this way rescue breathing can be continued for long periods without fatigue.

7. After performing rescue breathing for a period of time, you may notice that the casualty's stomach is bulging. This is due to air being blown into the stomach instead of the lungs. Although an inflation of the stomach is not dangerous, it makes inflation of the lungs more difficult. Do not attempt to reduce the stomach bulge as this may cause the victim to aspirate (Force vomitus into the lungs).
8. As soon as artificial respiration has been started and while it is being continued, an assistant should loosen any tight clothing about the casualty's neck, chest, or waist.
9. Continue artificial respiration without interruption, until natural breathing is restored or until a physician declares the patient dead.
10. To avoid strain on the heart when the patient revives, he or she should be kept lying down and not allowed to stand or sit up. The patient should be kept warm and given a warm drink, such as coffee or tea.
11. A brief return of natural respiration is not a certain indication for stopping the resuscitation. Not infrequently the patient, after a temporary recovery of respiration, stops breathing again. The patient must be watched, if natural breathing stops, artificial respiration should be resumed at once.

o Why must the first five to ten breaths be deep and at a rapid rate?

o What should you do if you see the victim's stomach bulging? _____

o How long should you continue artificial respiration? _____

SPECIFIC TYPES OF WOUNDS

The lifesaver steps: Stop the bleeding, prevent shock, and protect the wound, should be carried out when treating any person who has suffered injury.

Stop the Bleeding

First apply pressure to the wound with a dressing or any clean article of cloth. The dressing is placed against the wound and firm pressure should be applied as long as needed. If the wound is on an arm or leg, and if bleeding continues, place the patient in a prone position with the injured limb raised. The limbs should not be raised if broken bones are suspected.

If blood is gushing from the wound and the previously discussed methods of stopping the bleeding have failed, a tourniquet should be applied. The tourniquet should be tightened only enough to stop arterial bleeding (gushing of blood from the wound). Always place the tourniquet between the wound and the heart, in most cases just above the wound; however, in case of bleeding below the knee or elbow, a tourniquet should be placed above these joints.

The patient should be seen by a medical officer as soon as possible after the tourniquet is applied. The tourniquet should not be loosened by anyone except trained medical personnel.

o The three lifesaver steps are _____ , _____ , and _____ .

o When should you NOT raise a victim's limbs to control bleeding? _____

o When should a tourniquet be applied? _____

o Who should loosen the tourniquet? _____

Bleeding can often be reduced or stopped by applying hand or finger pressure at various points on a patient's body as indicated in Figure 4.

The pressure points in the groin and neck are particularly important. If the wound is too high on the leg for a tourniquet to be applied, the pressure points in the groin can be used. A neck pressure point should be used when the patient has a profusely bleeding scalp wound. Use the neck pressure point only when other methods of stopping the bleeding have failed. Do not apply pressure to both neck points at the same time or the blood supply to the brain will be critically reduced.

o Bleeding can be stopped by applying _____ or _____ pressure at various points on a victim's body.

o When is the only time you should use the neck pressure point?

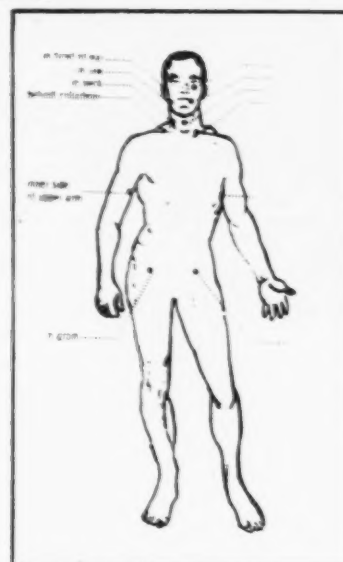


Figure 4. Pressure Points for Bleeding Control

Prevent or Treat Shock

Treatment for shock is started as soon as you come upon a casualty. Shock is a condition of great weakness of the body. It can, and often does, result in death, and may be caused by any type of injury. The more severe the injury, the more likely the occurrence of shock.

A person in shock may tremble and appear nervous. His or her pulse becomes rapid and weak. The patient may be excessively thirsty, and may become quite pale and wet with perspiration. He or she may gasp for air and may pass out.

A person may not go into shock for sometime after an injury; therefore, he or she should be treated for shock whether there are any shock symptoms or not. To prevent or treat shock, make the patient comfortable. Remove any bulky items the patient has been carrying. Loosen the belt and clothing. Handle the patient gently, and do not move him more than is absolutely necessary. If he or she is lying in an abnormal position, make sure no bones are broken before you attempt to straighten the person out. If there is no head wound, lower his or head and shoulders. If possible, raise the legs to increase the flow of blood to the brain. Patients with head wounds are treated as described in the section covering head wounds. Use a blanket, coat, etc, to keep him or her from becoming chilled. Be sure to put something under the patient to protect the body from the cold ground. If he or she is unconscious, place the patient face down with the head turned to one side. This position helps to prevent choking should vomiting occur. Once you have the patient in the proper position, don't move him or her because to do so might cause the blood pressure to drop.

o When should treatment of shock begin? _____

o What is shock? _____

- o The pulse of a victim in shock becomes _____ and _____.
 - o Why it is necessary to raise a patient's legs when treating for shock?
-
-

- o If the victim is unconscious why do you place him or her face down with the head to one side? _____
-

Heat Exhaustion and Heat Stroke

Heat exhaustion is brought on by extreme physical exertion in a hot environment and is a state of mild shock. Heat exhaustion is manifested by weakness, faintness, dizziness, headache, loss of appetite and nausea. Victim's skin will feel cold and clammy and will be perspiring. The body temperature will be about normal. The first aid procedure for heat exhaustion is to have the victim lie down in a cool room and be made comfortable. The victim may be given a drink of salt water, 1/2 teaspoon salt in 1/2 glass of water every 15 minutes for 3 or 4 doses only if conscious. Treat for shock by loosening victim's belt, and loosening tight clothing. When treated as indicated above, heat exhaustion should be promptly reversed and nonfatal. However, if prompt recovery is not seen after rest in a relatively cool area, the victim should be transported to a medical facility.

- o Heat exhaustion is caused by _____
 - o List the symptoms of heat exhaustion. _____
 - o List the first aid procedures for heat exhaustion. _____
 - o Under what circumstance should you definitely not give the heat exhaustion victim a drink of salt water? _____
 - o When should the first aid responder determine that a heat exhaustion victim should be transported to a medical facility? _____
-

Heatstroke, sometimes referred to as sunstroke is a failure of the heat regulating mechanism of the body. The body cannot rid itself of excess heat, normally accomplished by sweating. After sweating has ceased, heat will continue to build up in the body eventually resulting in cell damage in the Central Nervous System (brain and spinal cord). It is not necessary for the victim to be exposed to the sun for this very serious state to occur. The victim has usually worked in a warm humid environment for a long period of time. The heatstroke victim will have red or flushed, hot, dry skin, and a very high body temperature (sometimes reaching 105° or more). When heatstroke first occurs, victims pulse will be rapid and bounding. Later the pulse will be rapid and weak. The victim may have diminished cerebral functions or the victim may be in a coma or near coma. Heatstroke is a true emergency. All untreated victims of heat stroke will die. They may die even if treated. Permanent brain damage may result if the condition is allowed to persist for a significant period of time. First aid procedures for heat stroke are:

- a. Try to reduce the body temperature to below 100° if possible by immersing the victim in ice water, or by using wet sheets and a fan.
- b. Transport to nearest medical facility as a priority one emergency.
- c. Cooling treatment must be continued while transporting.

- o Heatstroke is also known as _____
- o Define heatstroke _____

- o How does the body normally rid itself of excess heat? _____

- o If excess heat continues to build up in the body, eventually what would result? _____

- o What has the victim usually done prior to a heat stroke? _____

- o List the symptoms of heat stroke. _____

- o List the first aid procedures for heat stroke. _____

HAND TOOLS

OBJECTIVE

To help you in identifying and selecting hand tools and special tools as used in refrigeration.

INTRODUCTION

Few words have so many meanings as the word "tools". Each workman has certain tools which are common to his or her job. In this lesson, only those tools you will be using in this career field will be discussed, since these will be most important to you.

INFORMATION

The following assignments will be referenced from various chapters in the Modern Refrigeration and Air Conditioning textbook. Complete the questions before day 2 class.

Answer these questions on a separate sheet of paper and be prepared to hand them in.

- o On page 52, which two tools are used to cut copper tubing?
- o In paragraph 2-30, which wrench is most desirable when working with nuts and bolts?
 - o Which wrench is least desirable?
 - o Under what conditions would a 6-point socket be preferred over a 12-point socket? (Para 2-31)
 - o If a bolt has a nominal size of 5/16, then it takes what size wrench for the head and nut? (Figure 2-45)
 - o This wrench looks like a box wrench but it has an opening in it; what is it? (Para 2-33)
 - o When using open end wrenches on refrigeration fittings, why is a thick jaw the better wrench? (Para 2-34)
 - o Is there a proper way to use an adjustable jaw wrench? If so, how? (Para 2-35)
 - o The service valve wrench has a square hole on the fixed end and what on the other? (Para 2-37)
 - o What is the fixed end of the service wrench used for? (Para 2-37)
 - o If you have a service wrench but it does not fit the valve stem on your equipment, then according to paragraph 2-38 what else do you need?
 - o In normal refrigeration work the type hammer you will use most is the 12- or 16-ounce _____ hammer. (Para 2-40)
 - o To prevent surface injury to parts while hammering on them, you should use a mallet made of _____, _____, _____, or _____. (Para 2-41)
 - o Paragraph 2-42 lists two types of wire cutting pliers; they are the _____ and _____.

- o What part of a screwdriver is not included in its length? (Para 2-43)
- o The size of a drill bit is usually found on the _____ of the drill. (Para 2-46)
- o The double cut file is used for what purpose? (Para 2-64)
- o Which hacksaw blade would be best for cutting copper tubing? (para 2-65)

ELECTRICAL PRINCIPLES AND CIRCUITS

OBJECTIVE

To help you attain a working knowledge of Electrical Principles and Circuits.

INTRODUCTION

You may question why a refrigeration mechanic needs to know electricity. The answer is simple. By far the largest amount of refrigeration troubles are in the electrical system. In order to train you in the most effective manner, we begin with simple fundamentals and increase your knowledge each day.

INFORMATION

The following assignments will be completed as indicated for days 2 thru 5. You will be given a quiz at the beginning of each day which will measure information from the designated section of this Study Guide Workbook.

Part 1

Read the following paragraphs and answer the questions prior to day 2 class.

MATTER

Matter is made of particles in motion. This moving-particle theory explains many common facts such as evaporation of liquids, diffusion of gases, and the flow of electrical current. However, before you can use the moving-particle theory to explain current flow, or why some materials such as copper, silver, and gold make good conductors of electricity and other materials very poor conductors, you must identify the particles of matter that do the moving.

To obtain the answer to these questions is the reason you are starting the study of electricity with a basic lesson on the structure of matter.

Structure of Matter

The earth and the planets, or anything found on, around, or in them are states of matter. It exists in millions of forms, from the clouds in the sky and our food and clothes, to the soils, liquids, metals, woods, and rocks of the earth.

These many forms of matter exist in three states - liquid, solid, and gas. As you know, liquids, solids, and gases occupy space and have weight; otherwise, we could not identify these states of matter. Therefore, everything around us is an example of matter in one form or another.

- ☐ True or false (Circle one). Matter is anything that has weight and occupies space.
- ☐ The three states of matter are _____, _____, and _____.

Long ago scientists discovered that the many forms of matter could be broken into smaller particles. One of the smallest particles to which matter can be broken down is the molecule.

Scientists call the smallest part of any common substance (matter) that still has the properties of the substance, a molecule. The very smallest bit of glass that can still be identified as glass is a glass molecule. The smallest bit of water that can be identified as water is a water molecule. Chemical methods can break down most molecules into still smaller particles. However, when the molecule is broken down into smaller particles, the characteristics of the original substance are destroyed.

o What is the smallest part of any common substance that still has the properties of the substance called? _____

o What happens to a molecule when it is broken down into smaller particles?

A substance which contains atoms of only one kind is called an element. By chemical action, we can combine elements to form completely new substances called compounds. If we break down water, we would have two atoms of hydrogen and one atom of oxygen. Water, then, is a compound formed by combining the atoms of oxygen and hydrogen. Rust is another compound, it is produced when the atoms of the iron element and the atoms of the oxygen element combine. Sugar, which is a compound, is composed of the elements of carbon, hydrogen, and oxygen. In other words, the atoms of most elements will combine with other kinds of atoms to form compounds. Salt, sugar, paper and water are all examples of compounds formed by a combination of elements.

o What is an element? _____

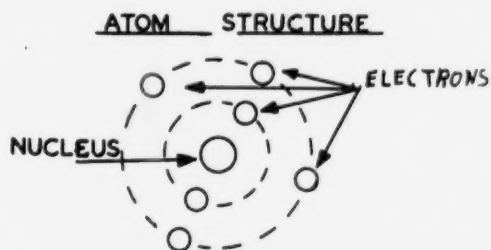
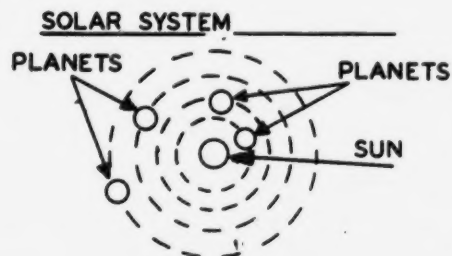
o What is a compound? _____

We have discovered that molecules are composed of very small particles known as atoms. An atom is the smallest particle that retains its identity as a part of the element from which it is divided. A further division of the atom would yield particles that bear no relationship to the original element from which they came. Now let us break down some matter and identify the atom.

Match the definitions with the list of terms by placing the number of the definition in the appropriate blank.

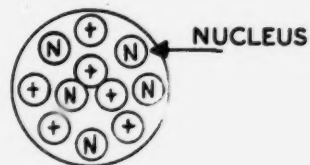
- | | |
|----------------|---|
| Matter _____ | 1. The smallest particle of an element that can take part in ordinary chemical change. |
| Molecule _____ | 2. A substance which is made up of different kinds of atoms in chemical combinations. |
| Atom _____ | 3. A substance which is made up of the same kind of atoms. |
| Element _____ | 4. The smallest particle into which a substance can be reduced and still retain the characteristics of the substance. |
| Compound _____ | 5. Anything which occupies space and has weight. |

All atoms are composed of tiny particles. The centermost part is known as the nucleus. The nucleus of an atom may be compared to the sun in our solar system around which planets revolve. The nucleus accounts for almost all the weight (mass) of the atom, and furnishes the force that causes other particles of the atom to spin around the nucleus in the same manner as the planets move in orbits around the sun. In the sketch below, notice the resemblance of an atom to our solar system.



- o The center most part of the atom is known as the _____.
- o The nucleus accounts for almost all the _____ of the atom.

The nucleus contains two of the three parts of the atom. These two parts are known as the proton and the neutron. The proton will always have a positive charge and every atom must have at least one proton in its nucleus. The symbol used to represent the proton is $+$. The neutron is a sub atomic particle found in the nucleus of the atom. Although it has a diameter and mass approximately equal to the proton, it has no electrical charge. Hence, it can be thought of as one proton and one electron. The neutron is required to stabilize the atomic structure of the more complex type atoms. Its symbol is N . The protons and the neutrons are packed closely together to form the nucleus of the atom. Since the neutron has no electrical charge and the proton has a positive charge, the nucleus of an atom will always have a positive ($+$) charge and is the particle that maintains the stability of the atom.



- o The atom contains the _____
- and the _____.
- o What type charge does the proton have?
_____.
- o True or false (circle one). The neutron does not affect the stability of the nucleus.
- o What type charge will the nucleus always have?
_____.

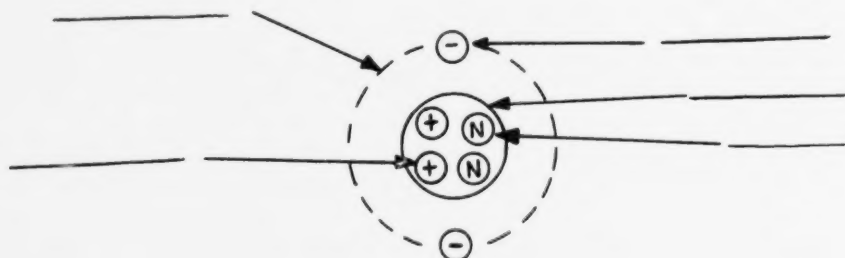
Read the paragraph below and answer the following questions.

The third part of the atom is the electron. Electrons are the particles that circle about the nucleus of an atom in paths called shells. There can be as many as seven (7) shells around the nucleus of an atom. Each shell will have a number of electrons orbiting in it. The number of electrons that each shell can hold depends upon the distance of the shell from the nucleus. However, the total number of electrons orbiting in the shells will be the same as the number of protons in the nucleus. The electron has a negative charge and the symbol is (-). It is this negative charge that helps hold the electrons in orbit around the nucleus.

o What is an electron? _____

o What type charge does an electron hold? _____

In the sketch of an atom shown below, identify the three parts of the atom by writing the word Electron, Proton, and Neutron in the appropriate blank.



One of the fundamental laws of electricity is that like charges repel each other, and unlike charges attract each other. This law explains the bond that exists in the atom between the positively (+) charged protons of the nucleus and the negatively (-) charged electrons orbiting around the nucleus. Since the two particles (electrons and protons) have unlike charges, they will be drawn toward each other until the positive charge exactly balances the negative charge. This balanced or neutral condition holds the electrons in the various orbits around the nucleus. Under normal conditions the number of electrons in the orbital shells of an atom will be the same as the number of protons in the nucleus. Therefore, if the sum of the positive charges exactly equals the sum of the negative charges, the atom will be neutral.

o Like charges _____ each other and unlike charges _____ each other.

o Under normal conditions what does the number of electrons in the orbital shell equal? _____

In the normal atom the sum of the positive charges of the protons in the nucleus exactly equals the sum of the negative charges of the electrons - such an atom is neutral. If for some reason a few electrons are torn away from the neutral atom, the atom becomes charged and is called a positive ion. Therefore, atoms having a positive charge are the result of an atom losing one or more of the orbiting electrons. In other words, a positively charged atom will have more protons in its nucleus than there are orbiting electrons.

o What is a positive ion? _____

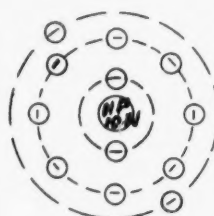
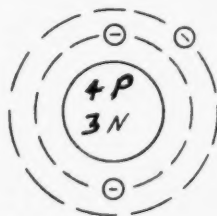
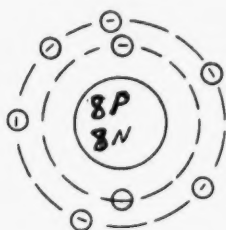
o Does a positively charged atom have more protons in it's nucleus than there are orbiting electrons? _____.

If the electrons that are torn away from the neutral atom (as explained in the previous paragraph) gather on some other neutral atom, that atom becomes negatively charged, and is called a negative ion. If an electron moved to an already neutral atom, the atom would then have an excess of electrons. The result would be the atom having a negative charge.

o what happens to the atom if it has an excess of electrons? _____

Now let us review the information on the electrical charges an atom may contain. We know that an atom may have a number of shells with a number of electrons orbiting in each shell, and normally there is one orbiting electron for each proton in the nucleus. The sum of the positive charges of the protons exactly equals the sum of the negative charges of the electrons. In other words, under normal conditions atoms are neutral; all atoms strive to remain electrically neutral. However, if for some reason a few electrons are torn away from a neutral atom, it has an excess of protons and is now a positively charged atom. If the electrons that are torn away from the neutral atom gather on some other neutral atom, it now has an excess of electrons and is a negatively charged atom.

Identify the electrical charge of each illustrated atom by writing the word Positive, Negative, or Neutral in the appropriate blank.



A _____

B _____

C _____

We observed that some electrons are close to the nucleus and others are farther away. The number of shells and the number of electrons in each shell depends upon the complexity of the atom. The shell closest to the nucleus can hold only two electrons. The next orbital shell can hold from one to eight electrons. The first shell must be filled with two electrons before any electrons can move into the second shell. Likewise, the second shell must be filled with its eight electrons before any electrons appear in the third shell. Therefore, if there are more than 10 electrons in the atom, an additional orbital shell farther away from the nucleus is required.

- o How many electrons can the shell closest to the atom hold? _____.

It is now apparent that the first shell can hold up to two electrons and the second shell can hold up to eight electrons. Also, each shell (first and second) must be filled completely before the third shell is formed. The requirement to fill the shell completely before the next shell is formed applies only to the first and second shells.

Continuing outward from the nucleus, the third shell can hold up to 18 electrons, the fourth shell up to 32 electrons, etc. However, the outer shell can hold only up to eight electrons. The next to the outer shell can hold only up to 18 electrons. When the outer shell is filled (8 electrons), and the next to the outer shell is filled (18 electrons), a new shell will be formed when another electron is added to the atom.

- o True or False (circle one). The requirement to fill the shell completely before the next shell is formed applies to all the shells.

- o How many electrons can the next to the outer shell hold? _____.

It is possible to determine whether a given substance will easily release electrons by noting the distance the shell is from the nucleus and the number of electrons in each shell. The first shell (the shell next to the nucleus) is complete and chemically stable when it has two electrons. The electrons, in this case, are bound tightly around the nucleus, and a great force is required to dislodge the electrons. The second shell must have eight electrons before it is complete or chemically stable. If the shell in question is complete, a superior force would also be required to remove the electrons. Now, if there are only two electrons in this second shell, it would surrender the electrons with relative ease. The unstable condition and distance the shell is from the nucleus permit the electrons to be easily dislodged from the atom.

- o True or False (circle one). The first shell is complete and chemically stable when it has one electron.

- o Will an atom that has two electrons in the second shell surrender these electrons easily? _____.

In other words, when the outermost shell of an atom has eight (8) electrons, the shell is stable and it will refuse to give up or take on additional electrons. We know that the other shells closer to the nucleus are also stable and will not give up electrons. Therefore, it is this outermost shell that determines if electrons can be drawn away from the atom by a small outside force. The outermost shell is called the valence shell and the electrons in this shell are called valence electrons. When the valence shell of an atom is more than half full (5 or more electrons) the atom tends to take on electrons to complete its shell and will refuse to give them up. If the valence shell is less than half full (3 or less) the atom tends to give up electrons. The fewer valence electrons there are in the valence shell, the easier it is to free them.

- o What is the outermost shell called? _____.

- o True or False (circle one). The fewer valence electrons there are in the valence shell, the easier it is to free them.

- o The outermost shell is stable when it contains _____ electrons.

Once an orbital electron is removed from an atom, it is called a free electron. The valence electrons of certain metals are so loosely bound to the nucleus that a small outside force can move the electron from the atom. The small amount of energy created by room temperature can cause an electron to be moved from the atom and become a free electron. This free electron may move in any direction through the metal in search of a positively charged atom. In other words, there is a random movement of electrons among the atoms within the metal.

o Once an orbital electron is removed from an atom what is it called? _____

It is apparent that the free electrons moving about the interior of the metal may again recombine with atoms. There is still an interchange of free electrons between atoms, but there is no general trend in either one direction or the other. The electrons do not actually flow from one end of the material to the other, unless they are forced to do so by the application of some external force. They are not considered as flowing in the sense that an electric current flows. In other words, to have a current flow, there must be a constant pressure to maintain a steady drift of electrons and a suitable path through which the electrons may flow.

o Name two requirements necessary to have current flow.

a. _____ b. _____

If a positively charged body (having too few electrons) and a negatively charged body (having an excess of electrons) are placed at opposite ends of the copper wire, the free electrons in the copper wire will be attracted to the positively charged body. The force caused by the two differently charged bodies cause all of the free electrons to move in the same direction through the wire. The random movement of electrons no longer prevails. The movement of these free electrons through the conducting copper wire toward the positively charged body constitutes an electric current.

o What will happen if you place two differently charged bodies at opposite ends of the wire. _____

When a battery is applied to the wire, an excess of electrons is applied to one end of the wire and a deficiency of electrons at the other end. The free electrons are caused to flow or drift toward the end with a deficiency of electrons. This is the same condition explained in the previous paragraph - two unlike charges. In the general drift of electrons along a wire carrying an electric current, each electron travels only a short distance before colliding with and becoming attached to an atom. However, this collision knocks off one or more electrons from the atom which become free electrons. In this manner the general drift continues throughout the entire length of the wire. This drift of electrons through the wire is referred to as a "FLOW OF CURRENT."

What is the flow of electron referred to? _____

Now let us review the information on the theory of current flow. The tendency of an atom to give up its electrons depends upon a characteristic called "Chemical Stability." An atom is said to be stable if its valence shell is full; that is, when the valence shell contains eight valence electrons. A great amount of force is required to dislodge the electrons of a chemically stable atom. When the valence shell of an atom is more than half full, the atom tends to take on electrons. When an atom's valence shell is less than half full, the atom will give up electrons. When a small amount of force is added to a valence electron, it will move out of the valence shell and become a free electron. If the movement of electrons is controlled so that the free electrons move in the same direction at the same time through a conducting material, we have a flow of electrons which is called electric current.

o The atom is said to be stable if its _____.

o What is the flow of electrons called? _____.

STOP! You have completed the material to be studied before day 2 class.

Start here for material to be accomplished prior to day 3 class.

Now that we know free electrons in the form of electrical current can be moved from point to point in a conducting material, the unit of measurement for electrical current can be presented. The negative charge of an electron is called an elemental charge, and it is the smallest electrical charge which has been discovered. The positive charge of a proton is also called an elemental charge. These charges are equal and opposite in electrical strength. Since the mobile member of the atom is the electron, it moves this charge through the conducting material. The rate at which the electrons move this charge through the material determines the amount of current flow.

- o What determines the amount of current flow? _____

The number of elemental charges that pass any point in a conducting material each second is the rate of flow of electrical current. However, the elemental charge is too small for practical use. This charge is so small that it would require several sheets of paper to record the amount of current used in your home in one day. We must have a number of elemental charges measured as a unit of current. This unit is called a coulomb. It takes 6,250 million billion elemental charges to make one coulomb. The coulomb is the unit quantity, or unit charge that is computed when determining the flow rate of current.

- o How many elemental charges does it take to make one coulomb? _____

The rate at which a current of water flows through a pipe is expressed as a certain number of gallons or cubic feet per second. In the same way, a current of electricity may be expressed as a certain quantity of charge flowing per second past a certain point in the conducting material. As you know, we use the coulomb as the quantity of charge that goes by per second. The rate at which the unit charge flow is measured is amperes. If one coulomb passes a point each second, the current flow would be one ampere. Therefore, ampere is the number of coulombs passing a point per second in a conducting material. The unit of measure used to express the rate at which current flows is the ampere.

- o What is a coulomb? _____

- o What is the unit of measure used to express the rate of current flow? _____

Now that we know that current is the movement of electrons through a conducting material, and the total amount of charge transferred by the moving electrons is measured in amperes, let us discuss the force that causes the movement of the electrons. You should remember that when a wire is connected between a point with an excessive number of electrons and another point with a deficiency of electrons, there will be a movement of the free electrons. This movement is explained by the fact that an electrical pressure exists whenever there are more electrons at one point than at the other. The greater the difference in the number of electrons, the greater the electrical pressure and the greater the amount of electron flow. This electrical pressure between the two points is known as a difference of potential.

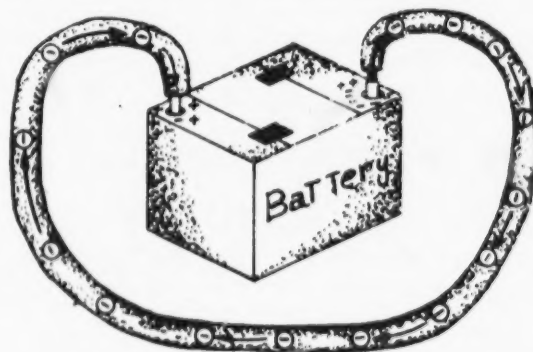
- o What will happen when you connect a wire between a point with an excess of electrons and a point with a deficiency of electrons? _____

- o What is the electrical pressure between two points known as? _____

When two bodies have unequal charges, a difference of potential exists between them. This difference of potential causes a current to flow. However, the drift of the electrons will tend to neutralize the unequal charge of the two bodies and no difference of potential will exist. Therefore, we must have a force that will maintain the difference of potential between the two bodies. In other words, we must have a force that will remove electrons from one point and pile up electrons on the other. This force is known as electromotive force. Now, if a device that causes a continuous electromotive force is connected between two points, a difference of potential is maintained and a continuous current will flow.

- o Difference of potential causes _____.
- o True or False (circle one). The force that will remove electrons from one point and pile up electrons on another point is known as electromotive force.

In order to maintain a steady flow of current, we must have a continuous electromotive force. That is, one end of the wire must have an excess of electrons and the other end a deficiency of electrons. Note in the illustration to the right that the electrons flow away from one post of the battery and toward the other post. The reason for this is that a battery creates an excess of electrons at one post and it has a deficiency of electrons at the other post. The battery then is a constant source of electromotive force.



- o The battery is a constant source of _____.
- o What is required to maintain a steady flow of current? _____.

This electromotive force, or pressure, is usually abbreviated "E. M. F." This EMF is expressed in units called "volts". The volt is a unit of electromotive force and is measured with a device called a voltmeter. When the EMF of a battery is mentioned, it is referred to as having a certain number of volts. The same is true of the wall plug in your house. When we measure the EMF of the plug, we say that there are 110 volts available.

- o What is the abbreviation for electromotive force? _____.
- o What is the unit of measure for electromotive force? _____.
- o What device do we use to measure electromotive force? _____.

To summarize: When two bodies have unequal charges, a difference of potential exists between them. This potential difference causes a current to flow. The two bodies are maintained at a continuous difference of potential because of a constant source of electromotive force which creates an excess of electrons at one point and a deficiency of electrons at the other point. This electromotive force driving the current is measured in volts. One volt, when steadily applied to a conducting material that has one unit of resistance, will produce a current of one ampere.

o One _____, when steadily applied to a conducting material that has one unit of resistance, will produce a current of _____.

In order to cause electrons to move in the same direction through a conducting material, an electromotive force must be available. Several methods can be used to supply the electromotive force. The voltaic cell is one way in which an electromotive force can be produced. The cell consists of two metals, such as zinc and copper, placed in a solution of acid and water. The resulting chemical reaction produces an electromotive force between the two metals. The zinc takes on a negative charge and the copper metal takes on a positive charge. The metals thus become positively and negatively charged respectively and in this case an electromotive force of about .5 volts is produced. The same action takes place in the common flashlight battery or automobile battery.

o What does the voltaic cell consist of? _____

o Does the zinc plate take on a positive or negative charge? _____

o What produces an electromotive force between the two metals? _____

Another method used to produce EMF is by heat. For example, a thermocouple is a device which converts heat directly into electromotive force. The thermocouple consists of two dissimilar metals in contact. The metals can be copper and iron or any other dissimilar metals. When a conducting material connects the dissimilar metals and the point of contact of the two is heated, an EMF is developed which causes current to flow in the connecting wire. Note that the copper gives up its free electrons which flow through the connecting wire to the iron. This gives a negative and positively charged body which causes current flow.

o _____ is another method used to produce EMF.

o What is a thermocouple? _____

The third method used to produce EMF is by magnetism. When a current flows through a conducting material a magnetic field is set up around the material. If we take a copper wire and form it into a coil, the magnetic field will be very strong. Now if we take another copper wire and move it through the magnetic field we will produce an electromotive force in the moving wire. In order to produce EMF by magnetism, we must have three necessary factors: a magnetic field, a conducting material, and relative motion.

o The third method used to produce EMF is by _____.

o What happens when current flows through a conducting material? _____

- o The three necessary factors to produce EMF by magnetism are:

1. _____
2. _____
3. _____

Now let us review. Current is the movement of free electrons through a conducting material. The unit charge transferred by moving electrons is expressed in coulombs. The rate at which the unit charge flow is measured in amperes. The external force or electrical pressure that cause a continuous current flow is known as electromotive force, and the unit of measurement for it is the volt. There are three methods of producing this EMF. One method utilizes chemical action between two different metals in a solution of acid and water. Another method utilizes two different metals and heat. The third method involves rotating conductors (wire) through a magnetic field. Each method creates more electrons at one point than at the other -- thus current flow.

- o What is current? _____
- o What is electromotive force? _____
- o Two methods of producing EMF are chemical and _____
- o What does the third method involve? _____

The drift of free electrons through a conducting material is called current flow. To set this stream of electrons in motion, we must have an electrical pressure which we call the electromotive force. Since an electrical current is dependent on moving electrons, any collision with other electrons or recombining with other atoms for a short period of time will tend to oppose or resist current flow in the conducting material. In other words, when electrons are forced through a conducting material, the friction between the electrons and atoms which form the material holds back the electron flow and this restriction is called opposition to current flow.

- o What is needed to set electrons in motion? _____
- o When electrons are forced through a conducting material, the restriction created is called _____

The opposition to the flow of current offered by a conducting material is called resistance. All conducting material has a certain amount of resistance. The amount of resistance in a material depends on the number of valence electrons that can be detached from the atom and become free electrons. Materials which offer the greatest opposition to current flow are those that will not easily give up the valence electrons around its atom. We say that these materials have high resistance.

- o What is the opposition to current flow called? _____
- o True or False (circle one). Materials that do not easily give up the valence electrons around its atoms are said to have high resistance.

- o The three necessary factors to produce EMF by magnetism are:

1. _____
2. _____
3. _____

The opposition of a material to a steady electron flow is called its resistance. The flow of current in a material depends upon its molecular structure and the ease with which electrons can be detached from the atom of the material. The easier it is to detach electrons from the atom, the more free electrons there are to contribute to the flow of current. The more electrons flowing the less resistance there is in the material.

- o The opposition of a material to steady electron flow is called _____

- o The more electrons flowing, the _____ resistance there is in the material.

- o The flow of current in a material is dependent upon

1. _____
2. _____

The unit of measurement for resistance is called an ohm, and the instrument by which resistance is measured is called an ohmmeter. Just as the volt and ampere are units of measurement, the ohm is a unit of measurement for resistance. When we measure the opposition of current flow of a material, we express the results in ohms of resistance.

- o What is the unit of measure for resistance? _____

- o What is the instrument used to measure resistance? _____

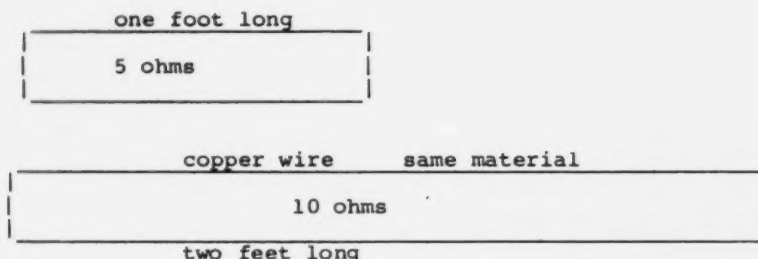
The opposition to the flow of current offered by a conducting material is called resistance. Now let's talk about some of the things that affect resistance. Different materials have a different resistance to the flow of electrons. Our lesson on Atomic Structure pointed out that some materials gave up electrons easier than others. Materials such as gold, silver, copper, and aluminum which have one, two, or three valence electrons make the best conducting material. The valence electrons of these materials can be easily removed from their atoms and become free electrons. If we apply an external force, we can move these electrons in a desired direction with very little opposition. Other materials such as wood, glass, and rubber, are composed of atoms with tightly held electrons. These materials offer considerable resistance to the transfer of electrons.

- o Materials such as _____, _____, _____ and _____ make the best conducting material.

- o Materials such as _____, _____, and _____ offer considerable resistance to current flow.

The type of material is probably the most important factor affecting the resistance of a material. However, there are other factors. The longer the conducting material, the higher the resistance is going to be. The resistance to moving electrons depends on the number of collisions with other electrons and atoms. Therefore, the greater the length of the material, the greater will be the number of collisions, and, consequently, the more resistance. If a conductor one foot long has a resistance of 5 ohms, then a conductor made of the same material two feet long would have 10 ohms resistance.

Study the illustration.

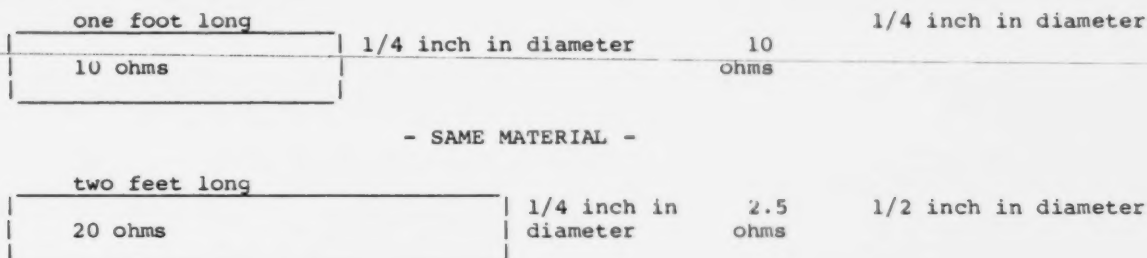


o Name two factors affecting the resistance of a conductor

1. _____
2. _____

The next factor is the cross-sectional area (how big around it is) of the material. The effect of the cross-sectional area is opposite the effect caused by the length of the material. A material one foot long and 1/4 inch in diameter has a resistance of 10 ohms. A conductor made of the same material, one foot long but 1/2 inch in diameter, would have 2.5 ohms of resistance. The greater the cross-sectional area, the greater space the electrons will have to move before bumping into other electrons or atoms. Reduce the collisions between electrons and resistance is reduced. The resistance of a material is directly proportional to the length and inversely proportional to the cross-sectional area of the material.

Study the illustration.



o The cross-sectional area is another factor that affects _____ .

o The resistance of a material is _____ proportional to the length and inversely proportional to the cross-sectional area.

We have covered three of the factors affecting the resistance of a material. They are the type, length, and cross-sectional area of the material. The fourth and last factor is the temperature. As heat is applied to a material, movement of electrons increases. This increase in electron movement causes more collisions between the electrons and these collisions cause the resistance to increase. If current is forced through a material that offers considerable opposition to the transfer of electrons, the temperature will be high. Current flow in any conducting material will produce some heat. However, it is the increase of the external temperature that will cause the increase of resistance in a material.

- o What is the fourth factor that affects resistance? _____.
- o Current flow in any conducting material will produce some _____.

In order to have current flow, the electrons must have a path to move through. An electrical circuit is a closed path for the flow of electrons. The starting point is some type of device to create electromotive force, such as a battery. The circuit is not complete until the conducting path can be traced back to the starting point where the electromotive force originates. This conducting path is known as a conductor.

- o What is an electrical circuit?
- o The conducting path is known as a _____.

Match the letter of each term to the appropriate definition in the left hand column.

<u>Definition</u>	<u>Term</u>
1. A unit of measurement for electromotive force _____	a. Volt
2. A unit of measurement for current flow _____	b. Ohm
3. A unit of measurement for resistance _____	c. Amperes
4. A path through which electrons can move _____	
5. Opposition to current flow _____	

A conductor is constructed of material that offers small opposition to the flow of electrons. Material of this type has valence electrons that easily become free electrons when an electromotive force is applied. In contrast to good conductors, some materials are composed of atoms with tightly held valence electrons. The valence shell is almost complete, and few electrons escape to become free electrons. Such materials offer great opposition to the movement of electrons between atoms. Materials which offer the greatest resistance to current flow are used as insulators.

- o What is a conductor made of? _____.
- o Materials which offer the greatest resistance to current flow are used as _____.

Now let's review the conductor - insulator area. Substances that permit the movement of a large number of free electrons are called conductors. The greater the number of electrons that can be made to move in a material under the application of a given electromotive force, the better are the conductive qualities of that material. An insulator is a substance that has few free electrons. Since current flow depends upon the movement of free electrons, the lack of free electrons in an insulator will prevent the flow of current. The insulation on the electrical wiring prevents the current from jumping to other devices or being knocked into space.

o What is a conductor? _____

o What is an insulator? _____

We said that a good conductor is a material that offers small opposition to the flow of electrons (current). Actually, what we are saying is that a good conductor will readily accept or give up its valence electrons. Thus, a very small force or amount of energy (electromotive force) will cause such electrons to be moved from the atom and become free electrons to contribute to the flow of current. Some of the materials that will do this for us are copper, aluminum, iron, platinum, and silver. In general all metals are good conductors.

o Will a good conductor readily accept or give up its valence electrons? _____.

o List 4 materials that make good conductors (1) _____

(2) _____ (3) _____ (4) _____

We said that an insulator is a material that offers great opposition to the movement of electrons. An insulator has electrons just as all materials have, but it has practically no free electrons. The valance electrons have combined with other valence electrons to complete the valence shell, leaving no free electrons available for current flow. Rubber, glass, paper, dry air, mica, and bakelite are examples of good insulating materials.

o Does an insulator have many free electrons? _____.

o Write the names of four good insulators.

1. _____
2. _____
3. _____
4. _____

It is incorrect to say that all materials are either conductors or insulators because there is no sharp dividing line. The best conductors are used to carry current and the poorest conductors are used as insulators to prevent current flow. All substance offers some opposition to current flow. This opposition is called resistance. Insulators have great resistance, while conductors have little resistance. The best insulators - that is, the poorest conductors are rubber, glass, paper, dry air, gas, mica, and bakelite. The best conductors are the metals and acids.

Identify the materials that are used as insulators and the materials used as conductors by placing an "I" or "C" in the appropriate blank.

Rubber	_____	Mica	_____
Glass	_____	Iron	_____
Paper	_____	Platinum	_____
Copper	_____	Silver	_____
Aluminum	_____	Bakelite	_____
Dry air	_____	Gas	_____

By now you should be familiar with the terms - electromotive force which is measured in volts, current which is measured in amperes, and resistance which is measured in ohms. When we speak of electromotive force, we will call it voltage. Voltage by itself does not contain energy, and voltage by itself can do no work. The same is true of current alone. To transmit energy and to do work, voltage and current must act together. If voltage and current are to act together, there must be a conductor for the current to move through, and some device to be acted upon. The conductor must start at the source of voltage, go to the device acted upon, and return to the source of voltage. We have described what is called an electrical circuit.

- o What is voltage? _____
- o To transmit energy and to do work, _____ and _____ must act together.

Now let's discuss the effects of current flow on the circuit and electrical devices. One effect of current flow is heat. The heating effect of current is produced when electrons are forced to move in a material which has high resistance. The movement of electrons in high resistance material produces high internal friction and results in the production of heat. The filament in lamp bulbs has such high resistance that when electrons move through this filament it heats to a white hot condition and gives off light. Current flow in any conductor will produce some heat, but to take advantage of the heating effect, high resistance materials are used. This heating effect is used in many places including electric stoves, heating pads, soldering irons, etc.

- o What is one effect of current flow? _____.
- o Why are high resistance materials used on electric stoves? _____

Current produces chemical action when it flows through a liquid. Example of this effect are the charging of a battery. The chemical reaction causes the acid to remove electrons from one plate and store them on the other plate. When an outside circuit is connected between the terminals of the plate, a current will flow until the solution of acid is neutralized by the materials of the battery plate. In this state, the battery is completely discharged and will not produce electromotive force. If a current is forced through the battery in an opposite direction, the chemical effect of the current will separate the acid elements from the plate material. The battery will be restored to its former charged condition. Other uses of the chemical effects of current flow include electroplating of metals, and commercial production of hydrogen, oxygen, and chlorine gases.

- o Current produces _____ action when it flows through a liquid.
- o Give one example where chemical action occurs? _____

The magnetic effect of current flow gives us the operation of telephones, telegraph, lifting magnets, electrical meters, motors, and transformers. This is perhaps the most used of the various effects of current flow. When current flows through a wire, a magnetic field is set up around the wire. The direction and strength of the magnetic field will be determined by the direction and strength of the current producing it. The magnetic field around a current carrying wire is composed of circular lines of magnetic force. As you know, electromotive force is produced by rotating a conductor through the field of force. The above named devices also operate in a similar manner because of the magnetic effect caused by current flow.

- o What will the strength of a magnetic field around a conductor be determined by?
_____.
- o How is electromotive force produced? _____
_____.

The shock effect of current is a very undesirable effect. This shock is caused by the passage of current through the body or a portion of the body and is caused by contact with a current-carrying conductor. The results are burns and a paralyzing effect on the heart and chest muscles. A current of only a fraction of an ampere flowing through the human body is usually fatal.

- o The most undesirable effect of current is _____.
- o What are the results of shock? _____

Current which flows steadily in the same direction such as the current flow caused by a battery is called direct current, and is abbreviated as DC. The current used in most appliances in your home, such as irons, lights, or refrigerators, does not flow steadily in the same direction but flows first in one direction and then in the opposite direction at regular intervals. It is produced by the magnetic field of a generator. This kind of current is called alternating current, and it is abbreviated as AC.

- o Current that flows in one direction is called _____.
- o What is current that flows first in one direction and then in the opposite direction called? _____.

MAGNETISM

Magnets

A magnet is of metal, usually iron or steel that has the characteristic of the capacity for becoming magnetized. Magnets have certain properties such as the ability to attract other magnetic materials. Studies show that all magnets are governed by certain natural laws.

Types of Magnets

A natural magnet as mentioned is a piece of magnetite, a kind of iron ore. The ancients knew the properties of this ore and called it lodestone, which means "leading stone". The only use found for it was in making magnetic compasses for telling direction. In modern times, scientists have discovered more about magnets and the relation of magnetism to electricity.

Artificial magnets are man-made magnets. Scientists have found ways to magnetize certain materials. Magnetic substances such as iron, steel, and nickel can be magnetized by using magnetic induction. Nonmagnetic materials such as glass, wood, etc., cannot be magnetized by any means.

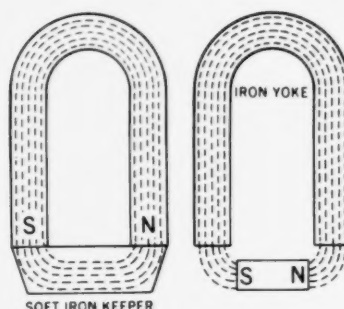
If the head of an iron nail is placed under a magnet so that its head touches the magnet, the lower end of the nail will hold up several tacks. The nail has been made into a magnet by touching the magnet. We say that the magnetism is induced into the nail. This is commonly called magnetic induction. Curiously enough, the nail does not need to be in contact with the magnet in order for magnetism to be induced. If you will bring the nail directly under the magnet but not touching it, the nail will still hold one or more tacks, showing that magnetism has been induced into it. However, in both cases, as soon as the magnet is removed, the nail will lose its magnetism. Thus, the magnetism induced in an iron nail makes it only a temporary magnet, because it loses its magnetism soon after it is removed from the magnetic field.

- o What type of materials are natural magnets made of? _____
- o What is magnetic induction? _____
- o What is a temporary magnet? _____

Magnets that keep their magnetism for a long period of time after being removed from a magnetic field are called permanent magnets. Magnets of this kind are usually made by an electric method. If you put a piece of iron and a piece of steel in a wire coil and pass dc current through the coil magnetizing them, they would both pick up about the same number of tacks while the current is on. But, when the current is turned off and the pieces are taken out of the coil of wire, you will find that the piece of steel will be able to pick up more tacks than the piece of iron. In fact, the iron usually loses most of its magnetism as soon as the current stops flowing through the coil of wire. One of the best permanent magnets made today is called Alnico. This is an alloy or a combination of metals. It is made of aluminum, nickel, iron, and cobalt. Steel is an alloy and, of course, is a good magnetic material.

The induced magnetism that remains in a magnet substance after the magnetizing force has been removed is called residual magnetism. Because steel and certain alloys hold magnetism for a long period of time, they are used to make permanent magnets. Iron, on the other hand, is used to make temporary magnets and is a temporary magnet.

Magnets are made in many shapes, according to their use. Common shapes are the bar and horseshoe magnets. A keeper (a piece of soft iron connecting the poles), should be kept on the magnet to enable it to maintain its strength. See Figure 5 for illustration of a keeper. Magnets are usually labeled North or South but, if they are not, there are ways of finding the polarity: bring it near a magnet of known polarity, suspend it from a string allowing it to point North and South, or use a compass.



A

B

Figure 5

- o What are permanent magnets? _____
- o The induced magnetism that remains in a magnetic substance after the magnetism has been removed is called _____ and _____.
- o Name 3 methods to find the polarity of an unmarked magnet.
 - o _____
 - o _____
 - o _____

Theory of Magnetism

In the theory of magnetism, it is usually assumed that all matter is made up of small molecules that act as though they were very small magnets. For magnetic materials like iron or steel, these magnets are strong; in all other materials, the magnets are weak. In a material not magnetized, the molecules align in no particular position and extend in every direction as shown in Figure 6A. When magnetized, all of the molecules

will line up, with their north poles pointing in one direction, as in Figure 6B. In soft iron, the molecules tend to return to their original position when the magnetizing force is removed, so the magnetism is temporary and the magnet is called a temporary magnet. In hard steel, the molecules tend to retain their magnetic position, and the magnet remains magnetized after the magnetism force is removed. The hard steel, therefore, becomes a permanent magnet. The magnetism that remains after the magnetic force is removed is known as RESIDUAL MAGNETISM, as previously mentioned. Heat and shock will destroy magnetism because they give the molecules an opportunity to return to their original position. If a magnet is broken, it will become as many small magnets as there are pieces. All combined will have the strength of the original. (See Figure 7.)

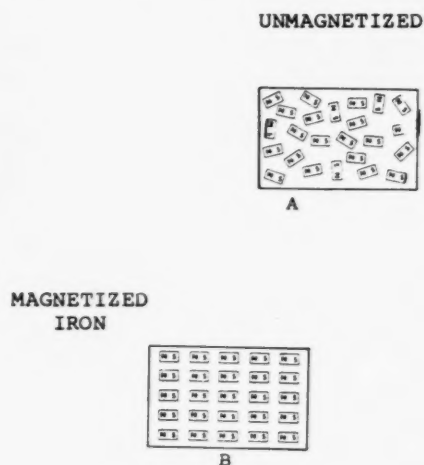


Figure 6

IRON

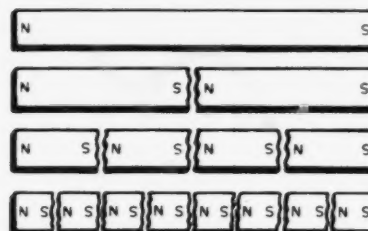


Figure 7. Effects of Breaking a Magnet

o What do the molecules do when a material is magnetized? _____

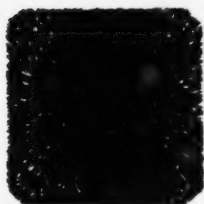
o What will heat and shock do to a magnet? _____

Magnetic Fields

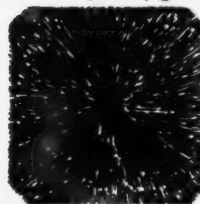
When a sheet of paper is placed over a bar magnet and iron filings are scattered over the paper, the filings will arrange themselves in definite paths or lines from one pole around to another. (See Figure 8.) This fact shows that magnetism acts as a force and arranges the particles in lines, which indicate the direction of magnetic attraction. These lines along which the magnetic forces act are called lines of magnetic force, lines of flux, and simply lines of force. The space around a magnet through which these forces act, and in which other magnetic material is affected, is called a magnetic field or simply the field of a magnet.

If the bar magnet, as shown in Figure 8, is held endwise to the paper, the filings will arrange themselves as shown in Figure 9. The positions taken by these filings indicate that the lines of force radiate from the north poles in all directions and enter the south pole.

BAR MAGNET



END OF BAR MAGNET



LONGITUDINAL VIEW

Figure 8

CROSS-SECTIONAL VIEW

Figure 9

o What are the lines called along which the magnetic forces act? _____

o What is the space around a magnet called? _____

It should be understood that these lines of force, as shown by the filings arise purely imaginary; therefore, it must not be assumed that the magnetic forces act along these lines only and nowhere else, such as between the lines. The strength of the magnetic field at any point decreases as the distance of the point from the magnet or other sources of magnetism increases.

DIRECTION OF LINES OF FORCE.
Every line of force of a magnet is assumed to pass out from the north through the surrounding medium, and return into the south pole; from there it passes through the magnet to the north pole again, as shown in Figure 10. The direction of the lines of force is indicated in this way, and the path that they take is called the magnetic circuit. Figure 11 also illustrates the above statement very well.

Although a line of force may apparently leave the end of a magnet and disappear into space as indicated by the arrangement of the iron filings shown in Figure 9, it must eventually return to the opposite pole of the same magnet.

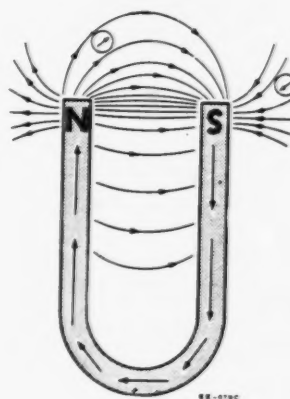


Figure 10

The direction of the lines of force in any magnetic field can be traced by several compasses as shown in Figure 12. The north pole of the needle will always point in the direction of the lines of force, or, in other words, the needle always turns so that its axis is parallel to the lines of force at that place.

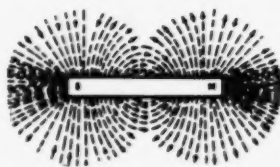


Figure 11

o What happens to the strength of the magnetic field as the distance from the magnet increases? _____

o If the lines of force leave the ends of a magnet must they return to the magnet? _____

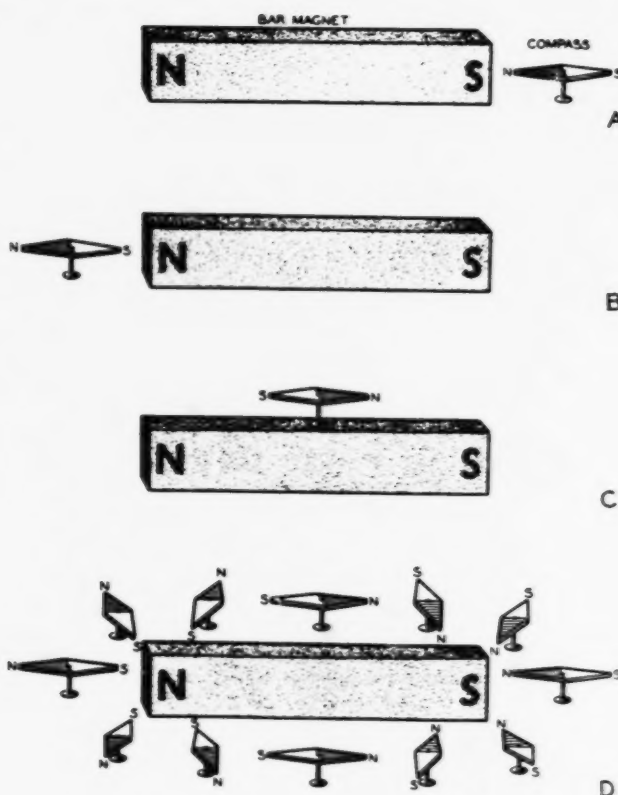


Figure 12. Effects of Magnetic Field on Compass Needle

ATTRACTION AND REPULSION. When a north pole of one magnet is placed near the south pole of another, the magnets will attract each other. The lines of force that come from the north pole of the first magnet move through air to the south pole of the second magnet, as shown by the iron filings in Figure 13.

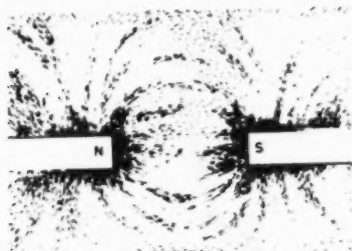


Figure 13

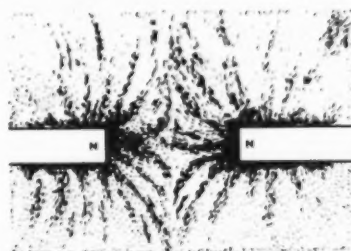


Figure 14

The lines of force continue through the second magnet, pass out to the air, and finally return to the south pole of the first magnet. The lines of force thus pass through both magnets, and the tension in these lines tends to pull the magnets together. The action is similar to that which would be experienced if the lines of force were replaced by stretched rubber bands.

When a north pole of one magnet is placed near the north pole of another, the magnets will repel each other. The lines of force may be represented by the iron filings above the magnets as before, but this time they will appear as shown in Figure 14.

There will be a crowding together of these lines of force as indicated, which explains the repelling action. Again these lines of force may be considered as rubber bands which, when crowded into a small space, exert a sidewise pressure on one another, thereby tending to separate the magnets. Note that the lines of force in this diagram do not intersect or the lines of force do not cross each other.

From the facts which have been stated and illustrated, the fundamental law of magnets is established: like poles repel each other, whereas unlike magnetic poles attract each other.

- o What will happen if you place a north pole of a magnet near a south pole of another magnet? _____.
- o What is the fundamental law of magnets? _____.

MAGNETIC INDUCTION. When a magnetic substance such as iron is brought into a magnetic field so that the magnetic lines of force pass through it, the substance immediately becomes magnetic. The lines of force are assumed to crowd together and tend to pass through the magnetic substance as indicated in figure 27 because it is a better conductor for lines of force than the surrounding air.

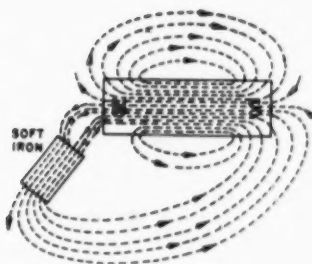


Figure 15

In this illustration, a small rectangular piece of iron is placed in the magnetic field of a bar magnet. The substance so magnetized is usually, however, only a temporary magnet. When it is removed from the magnetic field, its magnetism usually disappears. While under the influence of the magnetic field, the substance behaves as does any magnet and has polarity which is so distributed that its south pole is the one where the magnetic lines enter it; whereas its north pole is in that portion of substance where the magnetic lines leave it. This method of producing magnetism in a magnetic substance is called magnetic induction as previously mentioned.

o What is magnetic induction? _____

o Will the piece of soft iron in Figure 15 retain its magnetism when removed from the magnetic field? _____

MAGNETIC SCREEN. When a magnetic material such as soft iron is placed near a magnetic field, the lines of force of the field will tend to pass through the iron instead of the surrounding air, as the iron provides an easier path and is said to have high permeability. (See Figure 15.) This principle is used in the magnetic screen, which provides a space in the magnetic field that is free from the lines of force as indicated in Figure 16. The iron at (a) is rectangular in shape and the air space free from the flux (b) is shown at (c). This condition could not be obtained by surrounding the space by glass, porcelain, copper, or other nonmagnetic material, since the reluctance (opposition) to lines of force of these is about the same as that of air. The magnetic screen is sometimes used to shield delicate measuring instruments from stray fields and thereby increase their efficiency.

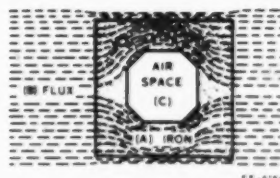


Figure 16

o What happens when soft iron is placed near a magnetic field? _____

o Why is a magnetic screen sometimes used with delicate measuring instruments? _____

Electromagnetism

You have studied both electricity and magnetism. Magnetism is a result of electricity and electricity is a result of magnetism.

The production of magnetism is accomplished by the fact that a current carrying conductor is surrounded by a magnetic field. Electricity is generated by a mechanical means (generator) and is created by electro-motive induction.

Electromagnets come in all shapes and sizes. Some are so small they will fit in the top of your pen and some are so large they can lift tons of iron. For example, a very powerful electromagnet has been invented. It is the size of a donut and weighs one pound, yet it has 33 times the strength of an old-type electromagnet weighing 20 tons. For every size and shape of electromagnet, there are many jobs such as doorbells, buzzers, relays, solenoids, meters, telephones, generators, motors, transformers, and so forth (see Figure 17).

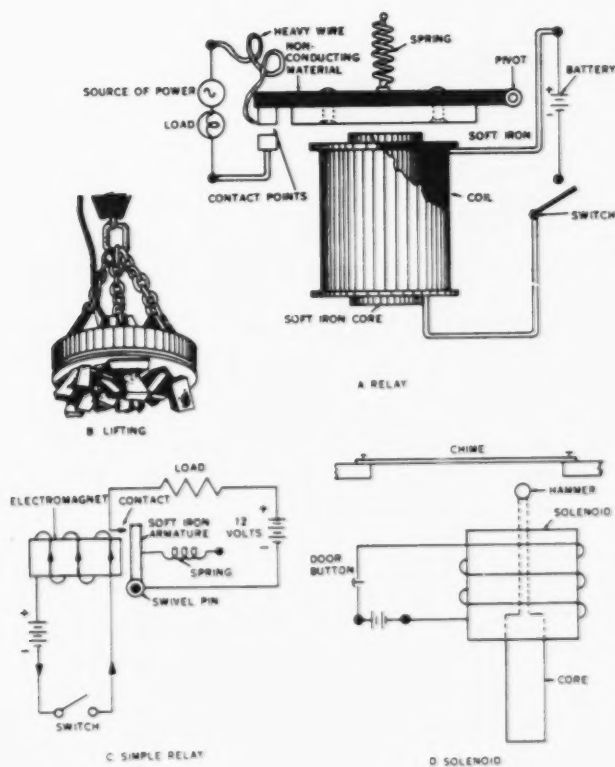


Figure 17. Uses of Electromagnetism

o What are some uses of electromagnets? _____

Electromagnets are like permanent magnets in their attraction but unlike in their control. Their attraction may be tremendous. They can, when properly constructed, hold tons of iron, but because these magnets are controlled by an electric current, the magnetism can be turned on and off with the flick of a switch.

Electromagnets are usually constructed with a coil of wire surrounding a soft iron core. To understand how electromagnetism works, you must understand the characteristics of conductors when they are carrying current.

o How are electromagnets usually constructed? _____

THE MAGNETIC FIELD AROUND A CONDUCTOR. All conductors carrying current are surrounded by a field of flux. This was discovered by Hans C. Oersted in 1820. This can be proven by connecting a wire to a battery and, as in Figure 18, dip the wire in iron filings. The filings are attracted and held to the wire. Now disconnect the wire--the filings will drop off. This is proof that the FIELD EXISTS ONLY WHEN CURRENT IS FLOWING.

o When does a magnetic field occur around a wire? _____

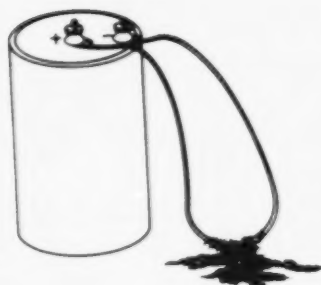


Figure 18. Magnetism Produced by Current

Visualize passing the conductor through a hole in a piece of cardboard as shown in Figure 19. Connect the wire to a battery and sprinkle iron filings on the cardboard. The filings outline the exact shape of the field.

Two characteristics stand out: (1) the field is circular around the conductor and (2) no lines cross.

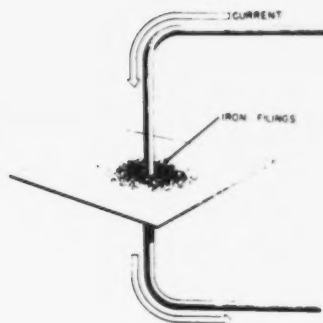


Figure 19. Magnetic Field Around a Conductor

- o What are two characteristics that stand out about current carrying conductors?

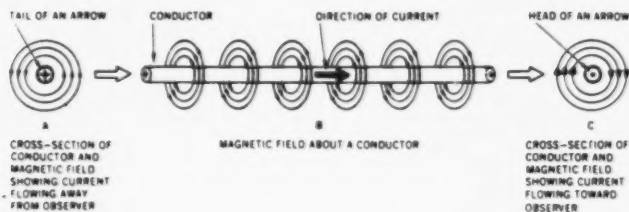


Figure 20. Magnetic Field About a Conductor

The magnetic field around a current-carrying conductor surrounds the wire for its entire length. (See Figure 20.) The field is strongest near the conductor and gets weaker the further you get away from the conductor. The magnetic circles around a conductor are in the same direction.

- o The magnetic field around a conductor is _____ near the conductor.

Place compasses around the conductor as shown in Figure 21. The "N" end of all compasses point in the direction of the magnetic lines of force. This shows that the magnetic lines of force are circular around the wire.

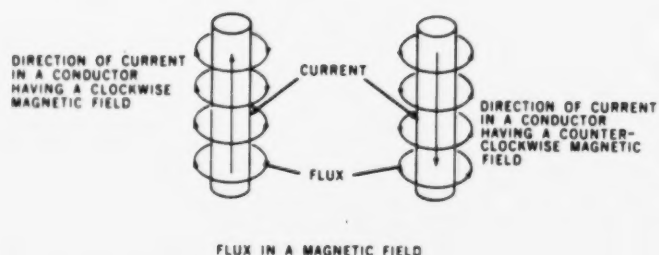


Figure 21. Direction of Magnetic Field Around a Conductor

Leave the compasses in place and reverse the current direction (switch battery connections). All the compass points now reverse. This shows that the direction of the magnetic lines of force are determined by the direction of current flow. This is commonly called the left-hand rule.

- o Direction of magnetic lines of force are determined by the direction of _____

The magnetic field around a single conductor is of little use since it is normally too weak to exercise much attraction. If you form a number of loops close together, you can concentrate the strength of the magnetic field and create polarity. It is important to have polarity since these are the points of greatest magnetic concentration (Figure 2234).

The strength of an electro-magnet is determined principally by three things: (1) the number of turns in a coil, (2) the amount of current flowing in the conductor, and (3) the type of material in the core.

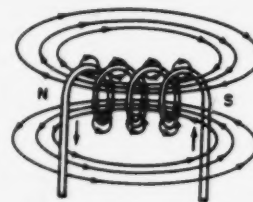


Figure 22. Conductor Formed Into Loop

- o List the factors that determine the strength of an electromagnet.
 - a. _____
 - b. _____
 - c. _____

ELECTROMAGNETIC INDUCTION. A magnetic field can be made to create an EMF (electromotive force, voltage), and thereby cause a current to flow in a closed loop. This creation of an EMF is accomplished by moving a conductor so that it cuts across lines of force, or by moving the lines of force so that they cut across the conductor. The relative motion is illustrated in figure 35.

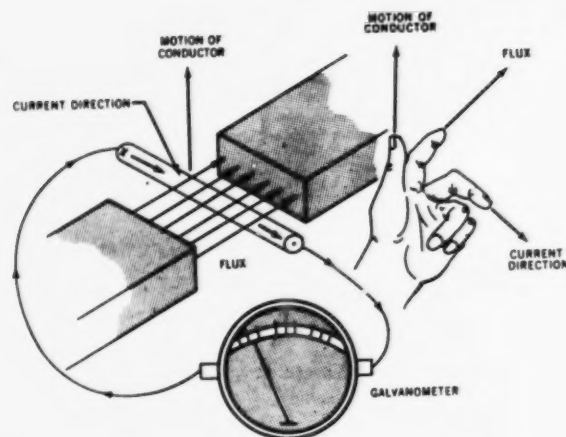


Figure 23

In Figure 23, if the conductor is moved back and forth between the pole faces so that its motion is parallel to the direction of the magnetic lines of force and therefore not cutting them, there will be no deflection on a meter connected to the conductor. This demonstrates that there is no induced voltage. As the angle between the lines of force and the path of the conductor is increased, the deflection on a meter increases until the maximum deflection is reached when the conductor is moving at right angles to the field. It may be stated, therefore, that a conductor moving parallel to magnetic lines of force will have no EMF induced in it, while one moving at right angles to the field will have a maximum EMF induced in it. This action leaves an excess of electrons at one end and a deficiency of electrons at the other end. This is voltage or difference in potential.

o How is an EMF created using a magnetic field? _____

o Will an EMF be induced when a conductor is moved parallel to the magnetic lines of force? _____.

STANDARD ELECTRICAL SYMBOLS

Switches: A switch is a device used to control the circuit by making or changing connections. Many different types of switches may be used to control a circuit. For Example:

SINGLE-POLE
SINGLE-THROW SWITCH



SINGLE-POLE
DOUBLE-THROW SWITCH



DOUBLE-POLE SINGLE-THROW



DOUBLE-POLE DOUBLE-THROW



o What is the purpose of a switch? _____

Overcurrent Devices

It is impossible for an electric current to flow through a conductor without heating the wire. As the temperature of the conductor increases, the insulation may become overheated and lead to insulation breakdown.

Overheating of conductors may become a serious fire hazard. To protect conductors and their insulation an overcurrent device is installed. Any device that limits the current in a conductor to a predetermined amperage is termed an overcurrent device.

o What occurs when electric current flows through a conductor? _____

o Why is overheating of a conductor dangerous? _____

There are many different types of overcurrent devices. The two most common types are fuses and circuit breakers.

Fuses (Plug Type)

There are several different types of fuses. The most common type fuse is called a "Plug Fuse". A plug fuse consists of a fusible link enclosed within a housing which is screwed into a socket similar to a lamp socket. The fusible link is a short length of metal ribbon or wire made to carry a predetermined amperage, but melts quickly when the current is too high. There is a window through which you can see if the fuse is melted or "Blown".

Plug type fuses range from 1 to 30 amperes. The maximum voltage rating for the plug-type fuse is 125 volts. Voltages exceeding 125 volts may "ARC" (jump) across the melted points and by-pass the overcurrent protection.



Plug-Type Fuse

- o What is the most common type fuse? _____
 - o What happens to the fusible link if the current becomes too high? _____
-
- o Plug type fuses range from _____ to _____ amperes.

Fuses (Cartridge Type)

The cartridge fuse is not commonly used in the home because of the high current rating. Most cartridge fuses are used in industrial areas and are the only type that can be used when current of more than 30 amperes is involved.

Cartridge fuses are divided into two types, the ferrule type and the knife-blade type. The ferrule type is used only on fuses rated from 1-60 amperes. The knife-blade type is used from 1-6000 amperes.



CARTRIDGE FUSE WITH
FERRULE CONTACTS



CARTRIDGE FUSE WITH
KNIFE-BLADE CONTACTS

Cartridge Fuses

Cartridge fuses are further divided into renewable and nonrenewable types. Since only the fusible link is destroyed when a fuse blows, renewable fuse links are available for replacement. The nonrenewable types, once blown, are of no further value, and the entire cartridge is replaced.

The diagrams below show standard electrical symbols for fuses.



Fuse



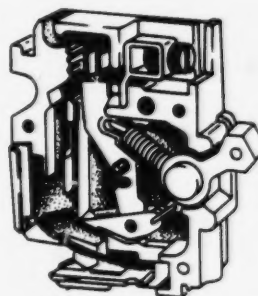
Fuse

o Why are cartridge fuses not commonly used in homes? _____

o The two main types of cartridge fuses are the _____ type and the _____ type.

Circuit Breakers

Circuit breakers are overcurrent devices designed to automatically trip or open the circuit on a predetermined overcurrent without injury to itself. When it opens a circuit, moving a handle, pushing a button, etc., closes the circuit again -- there is nothing to replace. The diagrams below are the standard electrical symbol for circuit breakers.



Internal View of a Common Type of Circuit Breaker



STANDARD CIRCUIT BREAKER



THERMAL CIRCUIT BREAKER



MAGNETIC CIRCUIT BREAKER

o What are circuit breakers designed to do? _____

o What must be replaced when a circuit breaker trips? _____

Much of your time will be spent troubleshooting equipment you are required to maintain. In order to understand how a system or a component operates, you must be able to identify the following electrical symbols:



BATTERY

D. C. Source of Power



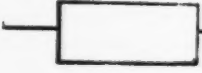
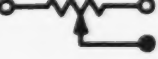
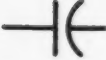
D. C. GENERATOR

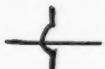
D. C. Source of Power



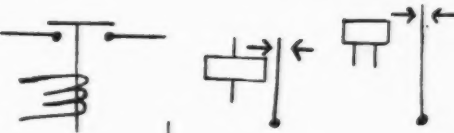
THERMOCOUPLE

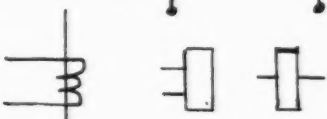
A device that generates electricity by joining two dissimilar metals and heating their junction (D.C. Power)

4.		ALTERNATOR	A. C. Source of Power
5.		Transformer	A device used to step-up or step-down voltage
6.	 	Motor	A device that transforms electrical energy into mechanical motion
7.		Lamp, light bulb	A device used to change electrical energy into light
8.	  	Coil	An electromagnetic device used in motors and controls
9.	 	Fixed Resistor	Devices used to control current in an electric circuit
10.	 	Variable Resistor or Rheostat	" " "
11.		Normally open contacts	Conducting parts which employ a junction that is opened or closed to interrupt or complete a circuit.
12.		Normally closed contacts	" " "
13.		Capacitor	An electrical storage device used in starting and/or running circuits of many electric motors.
14.		Diode	A solid state device which will allow more current flow in one direction in the circuit than in the other direction.
15.		Ground Connection	A conductor connected between a circuit and the ground.

16.  or  Conductors crossed, not joined Paths through which current can flow

17.  Conductors joined Path for current flow.

18.  Relays Electromagnetic mechanism in the central circuit which operates a valve or switch in an operating circuit.

 SOLENOIDS Electromagnetic with a moving core; operates a valve.

19.  AMMETER

20.  VOLTMETER TEST INSTRUMENTS

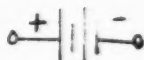
21.  OHMMETER

Match each electrical device with its symbol by placing the number of the device in the appropriate blank.

1. D. C. Generator

_____ 

2. Ammeter

_____ 

3. Transformer

_____ 

4. Battery

_____ 

5. Ground

_____ 

6. Motor

_____ 

7. Draw a symbol for a coil.

8. What is a capacitor? _____

9. Draw the symbol for a ground connection.

10. A resistor is a device used to control _____ in an electric circuit.

STOP! You have completed the directed Study to be completed prior to day 3 class.

Start here for material to be accomplished prior to day 4 class.

Electric circuits are represented by circuit diagrams where symbols are used to identify specific electrical units. Symbols can be combined in various ways to prepare different types of diagrams. Diagrams of various complexity are required, depending on the detail required for the task being performed.

o Electric circuits are represented by circuit diagrams where _____ are used to identify specific electrical units.

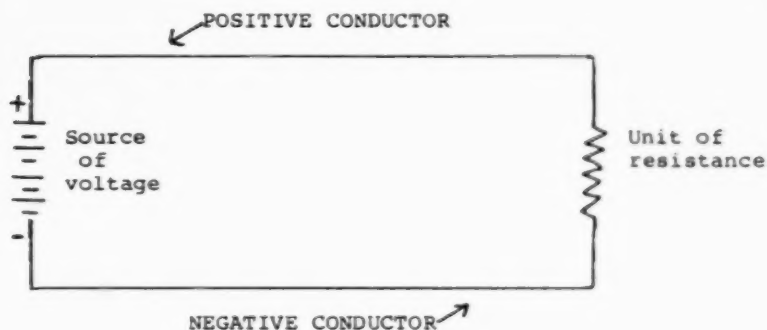
The relationships of current, voltage, and resistance must be considered in every electric circuit. Electrical current will flow only in a closed circuit which provides a continuous conducting path from the negative to the positive terminal of the voltage source. As discussed in this lesson, Ohm's law shows the relationship of voltage, current, and resistance in electrical circuits.

ELECTRICAL CIRCUITS

All circuits must have at least three parts. These parts are:

Source of voltage
Conductors

Unit of Resistance



The diagram above is a simple circuit. A simple circuit is a circuit with only one path for current to flow with one unit of resistance.

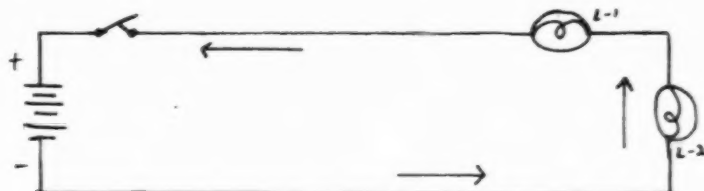
o Name the three basic parts of electrical circuits.

1. _____
2. _____
3. _____

o Define a simple circuit. _____

Series Circuits

A series circuit is defined as a circuit which has one path for current to flow with two or more units of resistance as shown in the figure below.



Note that the path of current flow is from the negative side of the battery through the switch, lamps L_1 and L_2 and back to the positive side of the battery. It is apparent that if the filament of any one lamp burns out (opens), the current path is no longer complete and the other lamps must also go out. Each unit of resistance is dependent on the other units.

o Define a series circuit. _____

o What happens to the series circuit if a lamp burns out? _____

You have seen that an electrical circuit consists of a source of potential connected to an electrical device which has resistance. When the circuit is completed, current flows in a closed path.

In 1827, George Simon Ohm discovered that the amount of current which flows in a circuit increases if the potential (voltage applied is increased), and decreases if the resistance of the circuit is increased. He also found that the current decreased when he decreased the potential applied, and increased if the resistance were decreased. These findings are known as Ohm's law which states that the current in a circuit is directly proportional to the applied voltage and inversely proportional to the resistance.

o What did George Simon Ohm discover about the relationship of voltage and current in a circuit? _____

o What did he discover about current when resistance is decreased? _____

Ohm's Law is expressed in formulas. These formulas are used to solve for values of current, voltage, and resistance in circuits. Before you can use these formulas you must learn the symbols for current, voltage, and resistance.

The electrical symbol for current is the letter "I".

The electrical symbol for voltage or electromotive force is "E".

The electrical symbol for resistance is "R".

a. E is the electrical symbol for _____ or

_____.

b. I is the electrical symbol for _____.

c. R is the electrical symbol for _____.

The Ohm's Law triangle will help you understand the relationship of current, voltage, and resistance. It will also aid you in determining the correct formulas for solving problems of electrical values.



The letters of this triangle are arranged into the following formulas to show the relationship of current, voltage, and resistance.

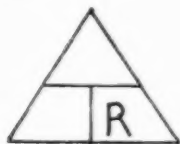
The formula for computing voltage is $E = I \times R$.

The formula for computing resistance is $R = E/I$.

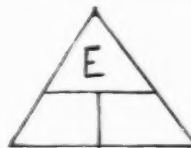
Now you use the Ohm's Law triangle to determine the formula for current. Write your answer in the space provided.

In the incomplete Ohm's Law triangles below, fill in the missing letters.

a.



b.



The three equations will enable you to find any one of the three factors (current, voltage, or resistance) if you know the other two. An easy way to remember the three relationships is to use the Ohm's Law triangle as shown in the diagram.



To find I (amperes), place thumb over I and divide E by R as indicated

$$I = \frac{E}{R}$$



To find R (ohms), place thumb over R and divide as indicated

$$R = \frac{E}{I}$$



To find E (volts), place thumb over E and multiply as indicated

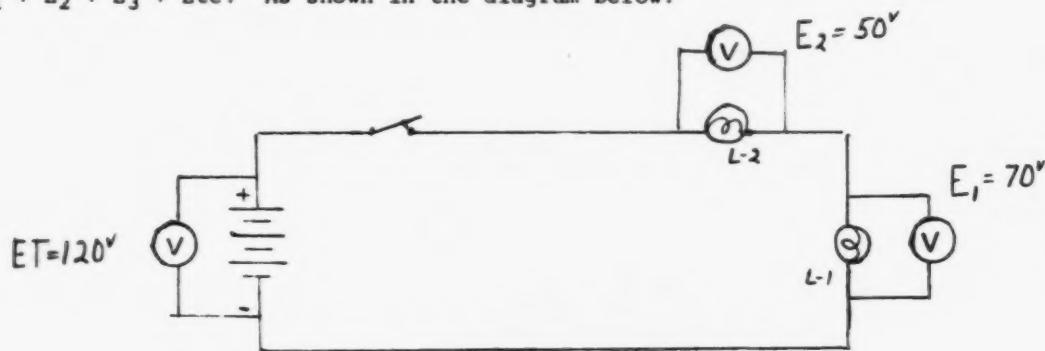
$$E = I \times R$$

The CHARACTERISTICS concerning the VOLTAGE, CURRENT, and RESISTANCE of a SERIES circuit are as follows:

VOLTAGE

The SUM of the voltage drops equal the TOTAL VOLTAGE. In other words, if you were to measure the voltage across each resistor with a voltmeter and add these voltages they would equal the total voltage or source voltage. Expressed mathematically,

$E_T = E_1 + E_2 + E_3 + \text{Etc.}$ As shown in the diagram below.



$$E_T = E_1 + E_2$$

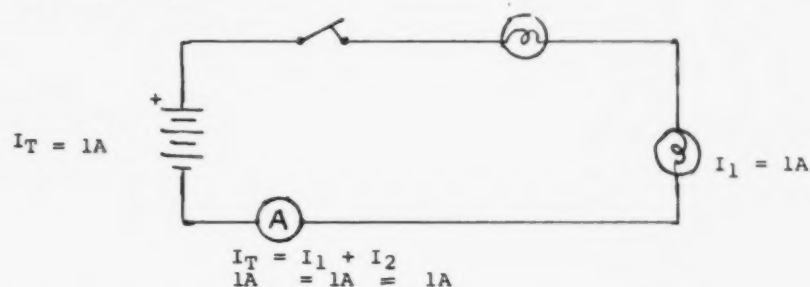
$$120v = 70v + 50v$$

- o In a series circuit the _____ of the voltage drops equal the _____ voltage.

CURRENT

The current is the SAME in each part of a series circuit. Explained mathematically,

$I_T = I_1 = I_2$. etc.



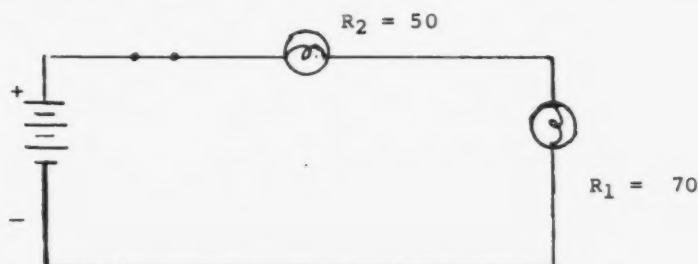
- o The current in a series circuit stays the _____ throughout the circuit.

RESISTANCE

The current which flows in the series circuit meets opposition from each unit of resistance in turn. If the units of resistance R_1 and R_2 were 70 and 50 ohms, respectively, the current in the circuit would meet a total opposition of 120 ohms. The three units of resistance would then offer the same opposition to the current in the circuit as one unit of resistance of 120 ohms. In a series circuit, the TOTAL RESISTANCE is equal to the SUM of the individual resistances. Expressed mathematically,

$R_T = R_1 + R_2 + R_3$, etc.

Where R_T is the total resistance and R_1 and R_2 are the resistance in series, see the diagram below.



$$R_T + R_1 + R_2$$

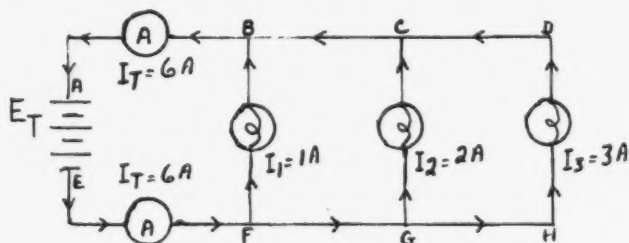
$$R_T + 70 + 50 = 120$$

o In a series circuit, the total resistance is equal to the _____ to the _____ of the individual resistances.

Parallel Circuits

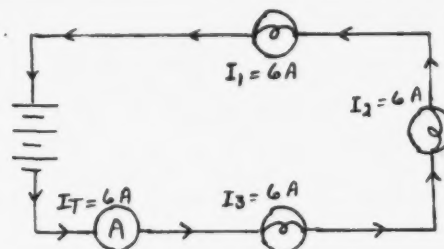
It is often necessary to connect electrical devices so that the entire source of voltage is across each device. A circuit in which two or more resistors are connected across the same source of EMF is a PARALLEL circuit. As in other types of circuits, there are characteristics that pertain only to parallel circuits. Parallel circuits are found in homes, barracks, hangars, etc.

Below is a parallel circuit, it consists of a battery and three electric lamps connected in parallel. Note that the current which leaves one terminal of the battery breaks up into three parts and then returns to the other terminal of the battery. Parallel circuits have more than one current path. (The other diagram is a series circuit for comparison.)



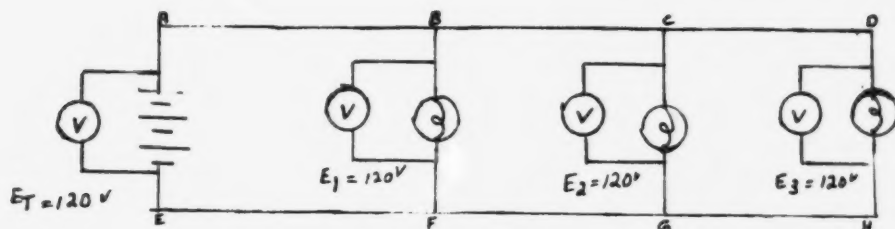
Parallel Circuit

VOLTAGE



Series Circuit

In the parallel circuit shown, note that points A, B, C and D are connected together and are one point electrically. Similarly points E, F, G and H, make up another electrical point. Since the applied voltage appears between points A and E, the same voltage appears between points B and F, between points C and G, as well as between points D and H. Thus, a rule or CHARACTERISTIC of parallel circuits would be that the VOLTAGE is the SAME or equal throughout the circuit. Expressed mathematically, $E_T = E_1 = E_2 = E_3$ where E_T is the applied voltage, E_1 is the voltage across R_1 , E_2 is the voltage across R_2 and E_3 is the voltage across R_3 . The VOLTAGE POTENTIAL across a resistor is commonly referred to as VOLTAGE drop.

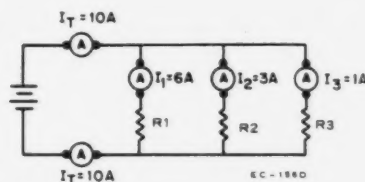


Computing Voltage in a Parallel Circuit

CURRENT

Another CHARACTERISTIC or rule of a parallel circuit is that the current flowing toward a point is equal to the current flowing away from the point. Therefore, $I_T = I_1 + I_2 + I_3$ etc., where I_T is the total current and I_1 , I_2 , and I_3 are the currents through R_1 , R_2 , and R_3 , respectively.

In other words, the TOTAL CURRENT in a PARALLEL circuit is equal to the SUM of currents passing through each individual branch as shown.



Computing Current in a Parallel Circuit

$$I_T = I_1 + I_2 + I_3$$

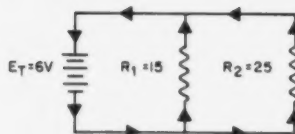
$$I_T = 6A. + 3A. + 1A. = 10A.$$

Problem:

Find I_T _____

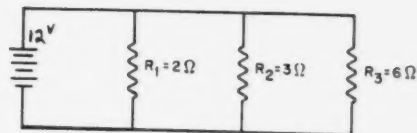
Given: $E_T = 6v$
 $R_1 = 15 \text{ ohm}$
 $R_2 = 25 \text{ ohm}$

Solution: $I_1 = E_1/R_1 = .4A$
 $I_2 = E_2/R_2 = .24 A$
 $I_T = I_1 + I_2$
 $I_T = .64 A$



RESISTANCE

There is a basic rule or CHARACTERISTIC concerning PARALLEL circuits that states "The TOTAL RESISTANCE in a parallel circuit is always SMALLER than the smallest branch resistance." In the figure, the parallel circuit has a 2-ohm, 3-ohm, and a 6-ohm resistor. The total equivalent resistance must be less than 2-ohms since it is the smallest branch resistor. R_T is less than 2-ohms.



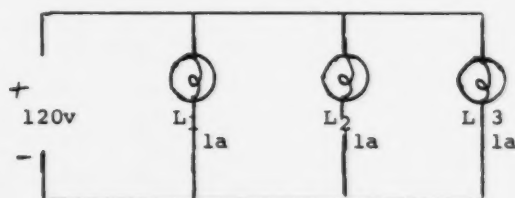
Parallel Circuit

One of the simpler ways of determining the total resistance of a parallel circuit involves making a matrix using the circuit values.

	R_1	R_2	R_3	Total
Voltage	12v	12v	12v	12v
Current	6A	4A	2A	12A
Resistance	2	3	6	1

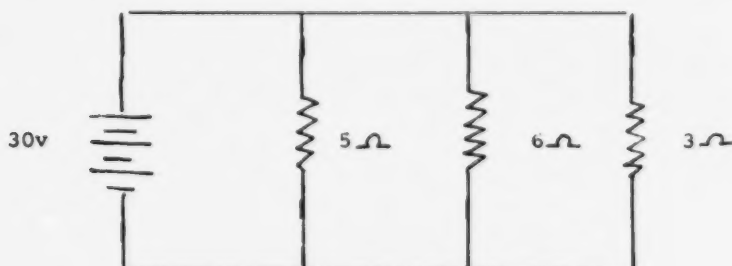
Notice that the voltage is constant throughout the circuit. Current thru each branch is computed and the total amperage divided into the applied voltage to obtain the total resistance. ($R_T = \frac{EA}{I_T}$)

Solve for total resistance in the following circuit.



	L_1	L_2	L_3	Total
Voltage	120	120	120	120
Current	1A	1A	1A	3A
Resistance	120	120	120	

Solve for total resistance in the following circuit.



$R_T =$ _____

SUMMARY

A parallel circuit has two or more units of resistance, or other electrical devices, connected across the same source of power and the current devices among the various branches. Each unit of resistance can be made independent of the other units. The voltage is equal in a parallel circuit or $E_T = E_1 = E_2$, etc. The total current equals the sum of the current passing through each branch or $I_T = I_1 + I_2$, etc. The total resistance in a parallel circuit is always less than the smallest branch resistance.

STOP! You have completed the assignment to be completed before day 4 class.

Start here for material to be accomplished prior to Day 5 class.

Directed study in preparation for Day 5

Read paragraph 6-11 (Modern Refr. and Air Conditioning textbook) and answer the following questions.

o Volts are units of _____

o What type of meter has been developed to measure electromotive force? _____

o The force needed to move one ampere through a one ohm resistance is called a _____

o Now many types of voltmeters are there? _____. What are they?

o Voltmeters are always connected in _____ with the circuit.

o What are the advantages of using a meter with electronic circuits instead of electromagnetic effects. _____

Familiarization of Multi-Meter Operation

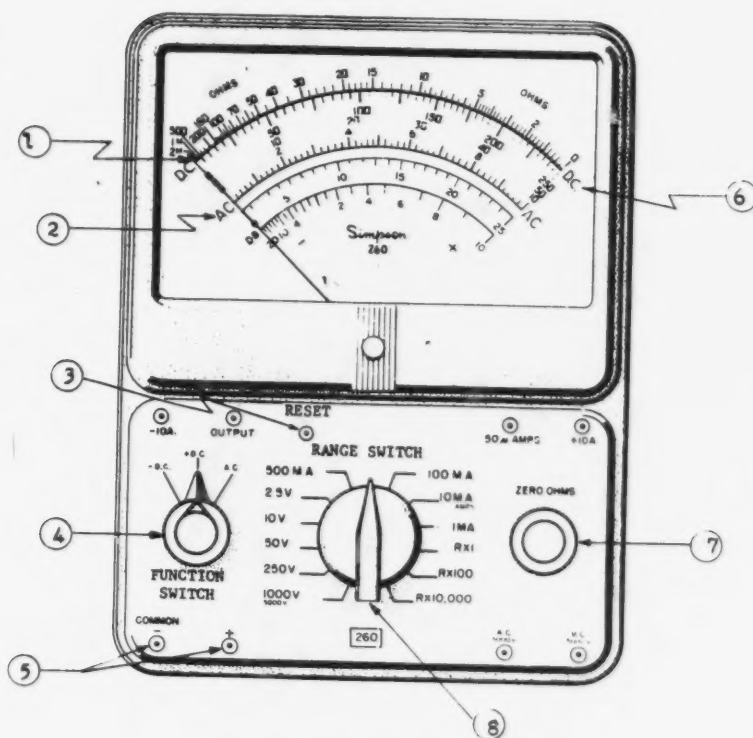


Figure 24

Refer to Figure 24 for proper location



1. Ohm scale. - used to measure circuit resistance - the more the needle moves to the right, the less resistance.



2. AC volt scale - a multi-range scale used to read alternating current.

3. **RESET**


Reset button - This is a manual reset switch to protect the meter in a overloaded condition.

4. 

Function switch - This decides what mode of operation or types of voltage to be read.

5. **COMMON**


Test lead jacks. This is the location of the test lead for low voltage (under 5000 volts)



6. D.C. Volt scale = scale shows the value of D.C. Voltage

7.

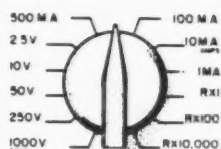
Zero OHMS Control

ZERO OHMS



The zero ohms control is located on the right side of the panel. This variable resistance in the ohmmeter circuit will be used to compensate for the aging of the internal batteries. Use it to adjust the meter indication to zero, at the right end of the scale, with the test leads shorted together. Whenever the ohmmeter circuit is used, make sure the leads are not left shorted.

8.



Range Switch

This determines the scale & the mode in which the meter will function.

Using Figure 25, list the names and purposes of the numbered elements in the spaces provided on p. 4-49.

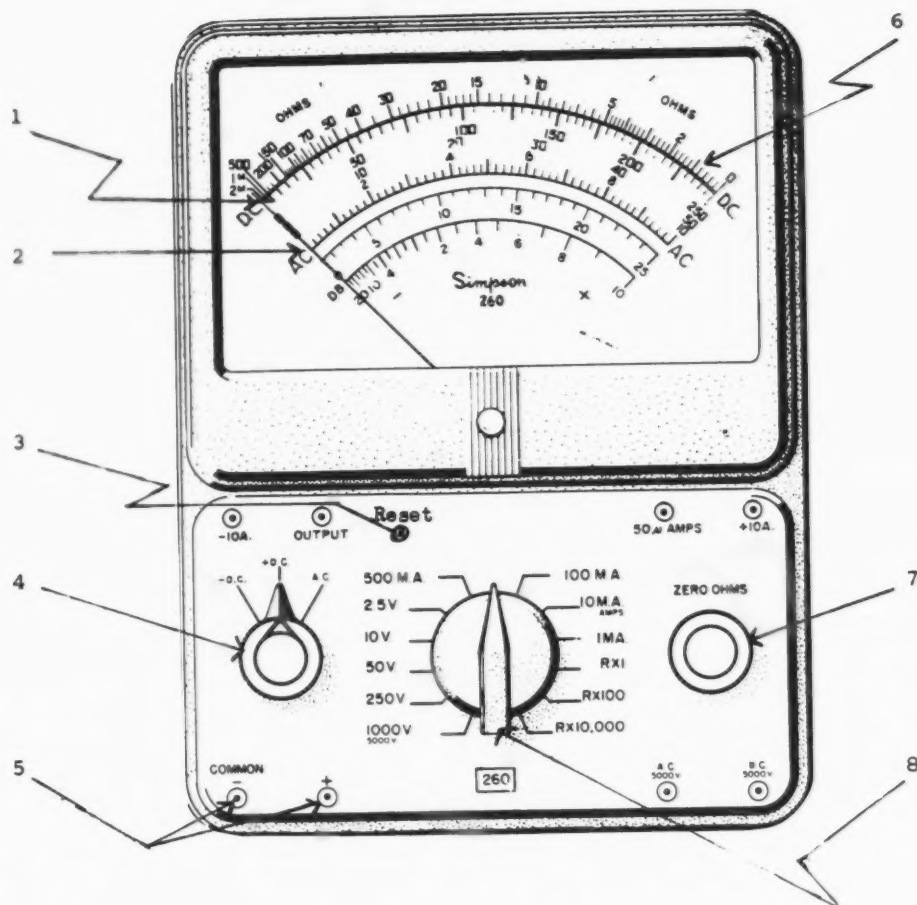


Figure 25

1. _____

_____.
2. _____

_____.
3. _____

_____.
4. _____

_____.
5. _____

_____.
6. _____

_____.
7. _____

_____.
8. _____

_____.

Homework

Read and be able to discuss prior to Day 5 lecture in class,
Paragraphs 6-14 through 6-22.

STOP! you have accomplished the assignment to be accomplished prior to Day 5 class.

WIRING SYSTEMS, MOTORS, MOTOR STARTERS AND OVERLOADS

OBJECTIVE

To help you in learning the:

- purpose and function of two, three, and four wire electrical systems.
- the general construction features of single and three phase motors.
- steps for installing and servicing electric motors.
- start and run windings of and electric motor, how to connect the motor and reverse its rotation.
- servicing procedure for motor starters
- types and function of electrical overload protectors.

INTRODUCTION

This study guide/workbook will prepare you for the instruction to be conducted in days 6, 7, and 8. You must accomplish the sections assigned for each day and be prepared for a test over the material when you come to class.

INFORMATION:

The following assignments will be referenced from various chapters in the Modern Refrigeration and Air Conditioning textbook.

1. Complete the following section during directed study time, in preparation for day 6 instruction.

- a. Two, three, and four wire electrical systems

A basic electrical service will consist of three main parts: generation, transmission, and distribution. You must become familiar with each of these parts in order to fully understand electrical services.

Generation

At every generating plant, some form of mechanical energy is used to produce electricity. The electricity generated at the plant is approximately 1200 volts, three phase. This 1200 volts leaves the generating plant and enters a step-up transformer.

Transmission

At the step-up transformer, the voltage is stepped up approximately one thousand volts for every mile it must be transmitted. Once the voltage reaches the general area to be served, it enters a substation. This substation contains step-down transformers which step the voltage down to a safer voltage (to approximately 13,000 volts).

Distribution

The voltage is taken from the substation and is run in all directions necessary to supply the general area. At the local area being served, the voltage is run through a distribution transformer which steps the voltage down to a usable voltage. (One distribution transformer may serve more than one building or other structure.) The voltage on the secondary side of the distribution transformer may be one of several types, depending on what is required within the building. Residential homes, for instance, may require 120/240 volt, single phase, while industrial plants may require 120/240 volt, three phase, or 277/480 volt, three phase.

Read paragraph 6-68 and answer the following questions.

- o List the three motor properties that must match the power source.

1. _____
2. _____
3. _____

- o List four standard voltages

1. _____
2. _____
3. _____
4. _____

- o List the three frequencies (Hertz)

1. _____
2. _____
3. _____

- o List the four phases

1. _____
2. _____
3. _____
4. _____

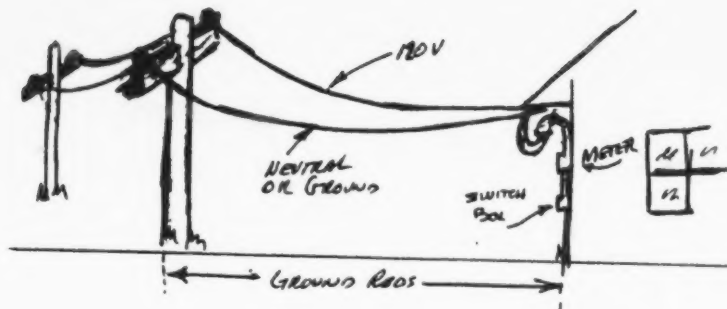
- o List four popular power electrical sources

1. _____
2. _____
3. _____
4. _____

Some common electrical systems are:

- Two wire - this system supplies only 110v AC.

If you see only two electrical wires going to a building, you know it has a two wire supply system and the only voltage is 110v.

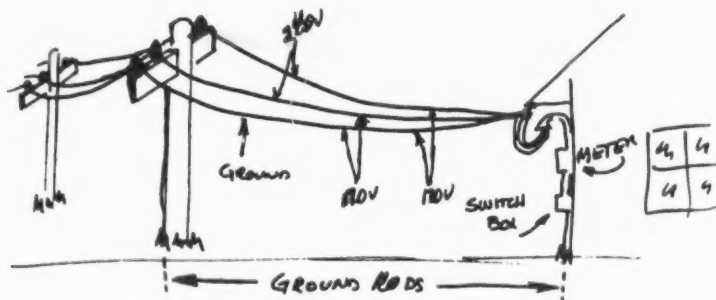


Two Wire Electrical System

o What voltage(s) can be obtained from a two wire system?

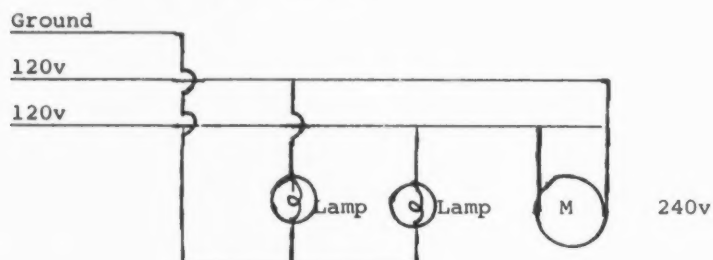
- Three wire electrical systems supply 110v or 220v AC.

If you see three wires going to a building you know that two voltages are present 110v and 220v.



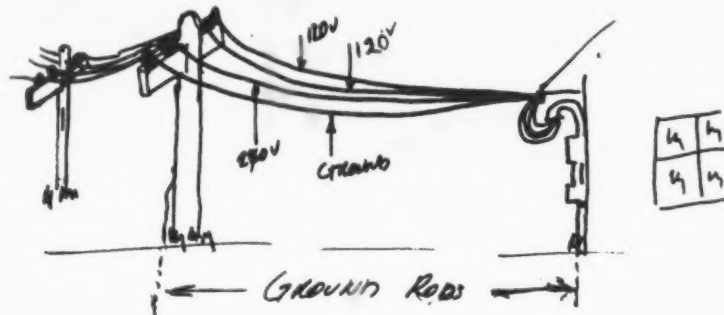
Three Wire Electrical System

Here's how it looks in use

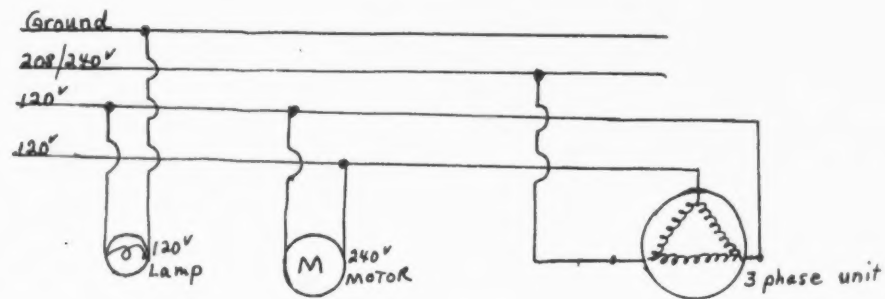


- o What voltage(s) can be obtained from this wire system?

- Four wire electrical systems supply 110v, 220volt single or three phase AC.



Here's how it looks in use.



o These are simplified illustrations to help you understand the concepts of two, three and four wire systems. Now refer to paragraph 6-69 and state the unit that supplies power to the secondary circuit(Homes, business and industries.) (Figure 6-76)

- o Refer to paragraph 6-70 and state the common types of transformers.

- o What are the voltages that can be obtained from the circuit shown in Figure 6-77.

- o How many wire systems is this? _____.

- o What would be the results of connecting a 2400 motor to wires A and C?

- o How many wires are used in the schematic shown in Figure 6-79? _____.

- o To operate a 240v air conditioner from this source, you would connect which leads to the air conditioner? _____.

Read the following paragraphs and answer the questions.

SINGLE PHASE INDUCTION MOTORS

Single-Phase Induction Motors

SPLIT-PHASE MOTORS. Split-phase motors are usually just fractional horsepower and are used to operate such devices as washing machines, small pumps, dryers and blowers.

Basically, a split-phase motor is constructed the same as a three-phase motor. It has a stator, rotor and two endbells. The windings are located and connected differently than they are in a three-phase motor. A centrifugal switch has been added to the rotor and one endbell. See Figure 26 below. A rotating part of the centrifugal switch is located on the rotor and a stationary part (containing a set of contacts) is located in the endbell. The purpose of this switch will be explained later in this study guide.

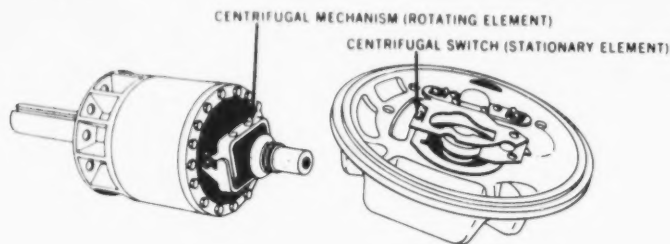


Figure 26 - Components of Centrifugal Switch

WINDINGS. The split-phase motor has two windings. One winding is of heavy insulated copper wire, which is generally located at the bottom of slots in the stator and are called "Run Windings" or "Main Windings." The other winding is called the "Start Winding" and is generally located in the stator on top of the run winding. The start winding and the run winding are connected to power until the motor reaches 75 percent of its maximum RPM. The centrifugal switch then disconnects the start winding from the power. The run winding is made up of many turns of heavy copper wire and the start winding is made up of fewer turns of small wire. If the start winding were not disconnected after a short period of time, it would burn up.

CENTRIFUGAL SWITCH. The rotating part of a centrifugal switch is a mechanical mechanism that relies on motion and flyweights to operate. As the rotor turns, the flyweights are pulled out by centrifugal force. This applies pressure to the closed contacts of the switch causing them to open. These contacts are in series with the start winding. The opening of the contacts will de-energize the start winding. See Figure 27

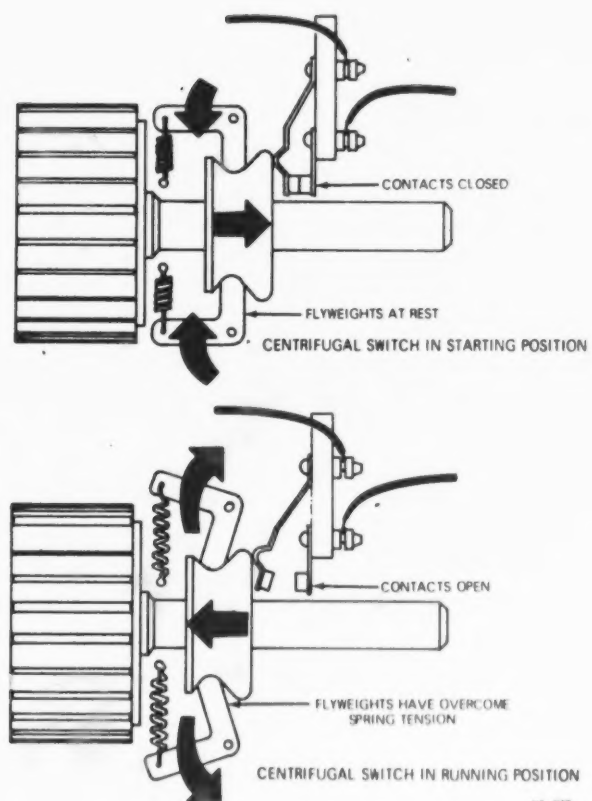


Figure 27 - Centrifugal Switch

OPERATION. When a split-phase motor is started, current flows through both the run and the start windings. This causes a magnetic field to be formed inside the motor stator. This magnetic field induces a current into the rotor, which, in turn, causes a magnetic field in the rotor. The magnetic fields in the stator and rotor combine in such a manner as to cause rotation of the rotor. The start winding is necessary at the start in order to produce the rotating field effect. After the motor is running, the start winding is no longer needed and is cut out of the circuit by means of the centrifugal switch. After the start windings are cut out, the motor operates on a shifting magnetic field.

Capacitor Motors

Capacitor motors are made in sizes ranging from 1/20 to 10 horsepower. They are widely used to operate refrigerators, washing machines, air compressors, air conditioners and fans.

CAPACITOR-START MOTOR. A capacitor-start motor is an improved version of the basic split-phase type motor. An intermittent type of capacitor is connected in series with the start winding. When the motor reaches 75 percent of full speed, the centrifugal switch cuts out the start windings and the capacitor. The capacitor added in the start windings gives the motor a greater starting torque than a basic split-phase motor.

To create a starting torque in a capacitor motor, a better rotating magnetic field has to be established inside the motor. This is accomplished by placing the start winding-out-of-phase with the run windings by more electrical degrees. A capacitor is used to cause the current in the start winding to reach its maximum value before the current in the run winding becomes maximum. Actually, the capacitor causes the current in the start winding to lead the current in the run winding. This causes a revolving magnetic field in the stator which induces a current in the rotor and causes it to rotate.

PERMANENT-SPLIT CAPACITOR MOTOR. The permanent-split capacitor consists of a standard split-phase type stator, a squirrel-cage rotor, a capacitor and endbells. This is another version of the basic split-phase motor. A permanent type capacitor is connected in series with the starting windings and left in the circuit at all times. The starting windings in this motor are not a high resistance winding and have the same number of turns and wire size as the run windings. The capacitor is used instead of resistance to give the split-phase effect. This eliminates the need for a centrifugal switch in this motor. The capacitor is continuously rated and is selected to give best operation at full speed while sacrificing starting torque. The permanent-split capacitor motor has the operating characteristics of poor starting torque with a high current draw, but runs with a good torque under load, at a constant speed.

o On split-phase motor motors, when is the start windings disconnected from the circuit? _____

o What is the purpose of the centrifugal switch? Explain. _____

o What is the purpose of the capacitor on a capacitor-start motor? _____

o The capacitor causes current to do what in relation of the start and run windings? _____

o What is the operating characteristics of a permanent-split capacitor motor? _____

STOP! You have completed the assignment to be done prior to Day 6 class.

Start here for material to be accomplished prior to Day 7 Class

Read the following paragraphs and answer the questions.

THREE-PHASE INDUCTION MOTORS

Three-Phase Induction Motors

Three-phase motors are simple in construction and relatively low in initial cost. The most common types of 3 ϕ motors are the squirrel-cage induction motors and the wound-rotor induction motor. These two types of motors vary only in the construction of the rotor. Three-phase motors are also broken down into three basic parts: (1) stator, (2) rotor and (3) end-bells.

Stator

The frame is made of cast iron or cast steel into which is pressed a laminated silicon steel core. The steel core is laminated to reduce "Eddy Currents", which is a loss due to stray currents. This steel core is constructed with semi-closed slots which hold the field windings. The field windings are made up of a number of varnished insulated coils, which are 120° (electrical) apart. These coils are insulated from the core with treated paper called fish paper. The coils are connected to form three separate windings.

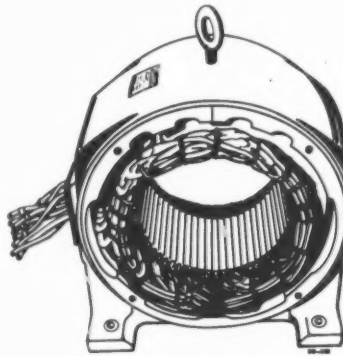


Figure 28 - Three-Phase Stator

The field windings and the steel core together make up the stator or stationary part of the motor. Figure 28 above shows the parts of a stator. The kind of rotor used inside of the three-phase stator determines the type of motor. There are two types of rotors, the squirrel-cage rotor and the wound rotor.

Squirrel-Cage Rotor

The squirrel-cage rotor consists of a laminated silicon steel core, rotor bars and end rings, mounted on a shaft. In the most recent types, the rotor bars are cast into place on an angle called skew. The skew effect increases the torque of the motor. The end rings short circuit or connect the rotor bars together. When one rotor bar is energized, all of them are energized. The rotor bars and end rings together make up a squirrel-cage winding. Fan blades are added on the end of the rotor to assist in providing adequate ventilation for cooling. See figure 29.

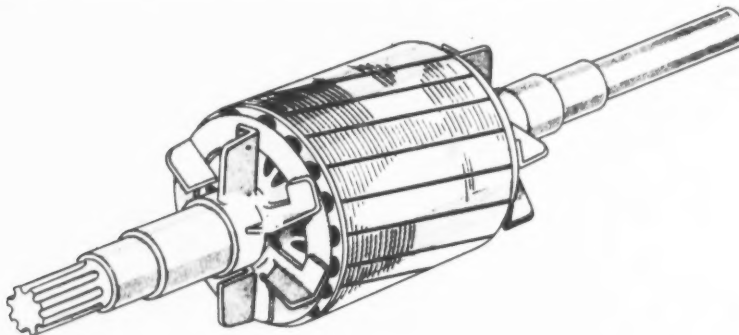


Figure 29. Squirrel-Cage Rotor

Wound Rotors

The wound rotor has a laminated silicon steel core mounted on a shaft. A rotor winding is wound around the core. The rotor windings are made of coils similar to those used in a stator. Each coil is made up of a number of turns of insulated copper wire. The windings are connected like those of the stator, wye or delta. When the rotor is connected for wye operation, one end of the windings are connected together in the center and the other end connected to slip rings mounted on the shaft. Brushes ride on the slip rings and are connected externally to resistors for variable speed control. When connected for delta operation, the windings are internally connected into a delta configuration and three leads are connected to the slip rings. Wound-rotor types of three-phase motors are used where a low starting current is desired with an external starting device. See Figure 30.

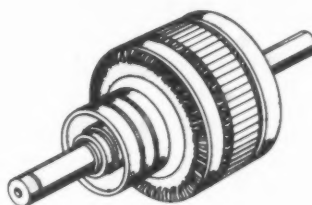


Figure 30. Three-Phase Wound Rotor

Endbells

The endbells serve three functions: (1) house the bearings, (2) support and align the rotor and shaft, and (3) complete the frame of the motor.

Principles of Operation

The effects of a rotating magnetic field around the stator are required to cause a three-phase motor to operate. This magnetic field is caused by three factors:

- _____ The difference in amount of current flow in the 3 ϕ power caused by the characteristics of 3 ϕ voltage generation.
- _____ Reversal in direction of current flow caused by the characteristics of ac voltage.
- _____ The arrangement of the field windings in the stator core to accomplish an even spread of magnetic field around the stator.

The rotating magnetic field is set up by the rising and falling current in the stator windings. When the current reaches its maximum value in one winding, a strong magnetic field is produced by the winding. As the current in the first winding decreases, the current in the next winding increases, causing the magnetic field to move to that winding. As the current decreases in the second winding, it increases in the third winding, causing the magnetic field to move again. The windings are distributed so that this rotation of the magnetic field is uniform and continuous. See figure 31.

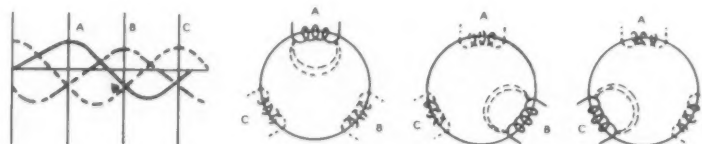


Figure 31. Rotating Magnetic Field

o What are two most common types of three-phase motors?

1. _____
2. _____

o What are the three basic parts of a three-phase motor?

1. _____
2. _____
3. _____
4. _____

o Why is the steel core of the stator laminated? _____

o What two components make up the stator? _____

o What determines the type of motor? _____

o What are two types of rotors?

1. _____
2. _____

o On a squirrel-cage rotor, what is the purpose of the skew effect? _____

o When is the wound rotor type of three-phase motor used? _____

o What are 3 functions of endbells?

1. _____
2. _____
3. _____

o What is required for a three-phase motor to operate? _____

Start here for the assignment to be completed prior to Day 7 class.

SERVICING ELECTRIC MOTORS

a. Read paragraphs 14-87 and 14-89, then answer the following questions.

° What is the first step to remove an electric motor? _____

° Why would you label the terminals and wires? _____

° How many hold-down bolts are normally used to secure the motor? _____

° What instrument is required to check the alignment of the motor? _____

° Why would you turn the motor by hand before turning the power on? _____

b. Read paragraphs 7-34 and 7-39, then answer the following questions.

° What will be the major portion of your job? _____

° What are the two classifications of troubles found in motors? _____

1. _____

2. _____

° What effect would frequent starting of a motor have? _____

° What is indicated if the motor will not start until the pulley is spun? _____

° Excessive vibration is an example of what category of trouble? _____

c. Read paragraphs 7-40 and 7-41, then answer the following questions.

o What are the two methods of bearing lubrication on open motors with bronze bushings?

1. _____

2. _____

o When using the ring lubricating method, what is the specifications of the oil to be used? _____

o How often should motors be greased? _____

o What is the possible cause if the rotor is hitting the stator? _____

o What effect would too heavy oil have on a bearing? _____

d. Read paragraph 7-42 and answer the following questions.

o How often should motors be cleaned? Why? _____

o What precautions should be observed when using cleaning fluids? _____

e. Read paragraphs 7-47, 7-48, and 7-49, then answer the following questions.

o What are two major operations involved in servicing hermetic motors? _____

1. _____

2. _____

o Majority of trouble found in hermetic motors falls in what category? _____

o What test instrument would be used to check the resistance of a coil? _____

DETERMINING START AND RUN WINDINGS OF ELECTRIC MOTOR

a. Read paragraph 7-10 and answer the following questions.

- o What major component of an electric motor contains the start and run windings? _____.
- o During starting, current goes through what windings? _____
_____.
- o Which of the windings has the heavier wires? _____
_____.

b. Refer to Fig 7-73 and answer the following questions.

- o What should the ohmmeter reading be on the run winding of a 1/8 HP motor?

_____.
- o What should the ohmmeter reading be on the start winding of a 1/8 HP Motor?

_____.

c. Read the following paragraphs and answer the questions.

Motor Connections

A three-phase motor has both internal and external connections. The internal connections determine whether the three sets of stator windings are connected delta or wye. The external connections are made with leads which are brought out to the terminal box of the motor. These leads provide a means of connecting the motor to a source of power.

Internal Connections

The two main types of internal connections used in three-phase motors are the wye and the delta.

The symbol for a wye connected motor is the symbol . Figure 32 is a schematic diagram of a wye-connected motor for high voltage.

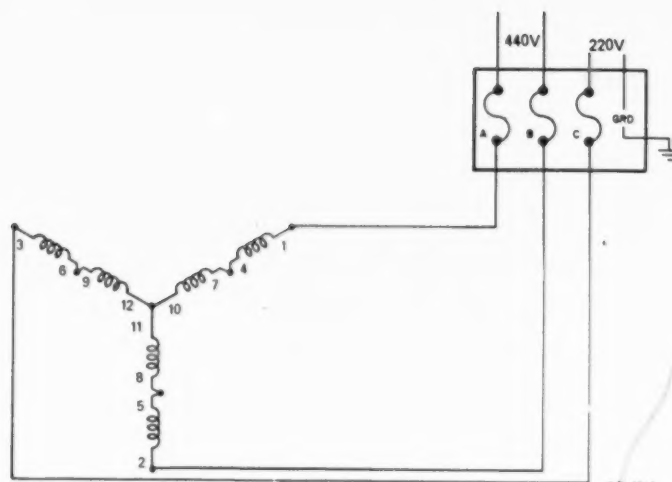


Figure 32 - 440-Volt Circuit Diagram

NOTE: The schematic diagrams shown do not illustrate the true position of the coils in the stator.

Figure 33 shows a schematic diagram of a wye-connected motor for low voltage.

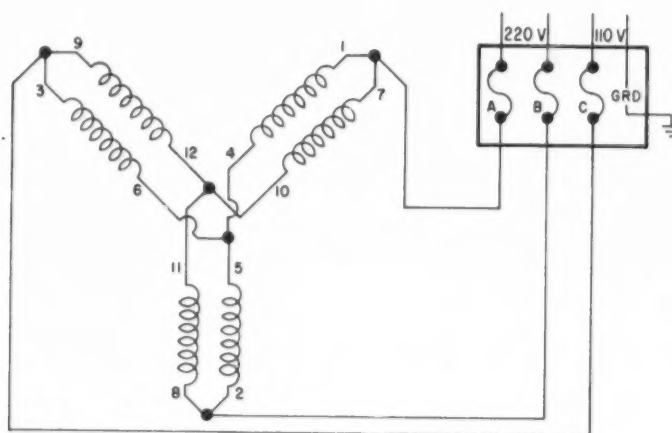


Figure 33 - 220-Volt Circuit Diagram

The symbol for a delta-connected motor is the Greek letter delta Δ .

Figure 34 shows a schematic diagram of delta-connected motor for high voltage.

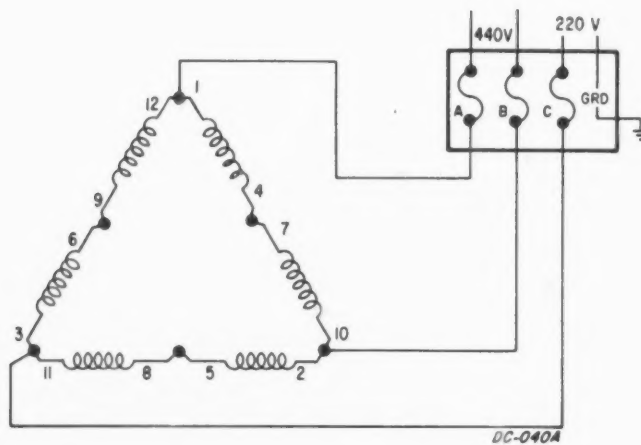


Figure 34 - 440-Volt Circuit diagram

Below Figure 35 shows a schematic diagram of a delta-connected motor for low voltage.

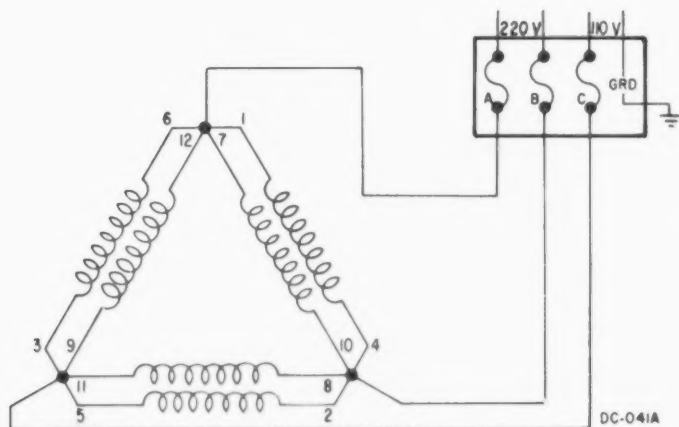


Figure 35 - 220 Volt Circuit Diagram

o What are two types of connections that are used on three-phase motors?

1. _____

2. _____

o What are two main types of internal connections used in three-phase motors?

1. _____

2. _____

o Why are the leads brought out of the terminal box of the motor? _____

o What is the symbol for a wye-connected motor? _____

o What is the symbol for a wye-connected motor? _____

o What is the symbol for a Delta-connected motor? _____

d. Read paragraph 7-21 and answer the following questions.

o How many terminals does a three-phase motor usually have? _____

o What are the common voltages used on three-phase motors? _____

o What does a three-phase motor require in place of the usual starting relays? _____

e. Read the following paragraphs and answer the questions

Single-Phase Motor Connections

Split-phase and capacitor start motors are made for either single or dual voltage operation. The single voltage, non-reversible type will have only two leads-- 1 and 2. The single voltage reversible motor will have four leads numbered 1, 2, 5, and 8. A dual voltage non-reversible motor will have four leads numbered 1, 2, 3, and 4. The dual voltage reversible motor leads will be numbered 1, 2, 3, 4, 5, and 8. Leads numbered 6 and 7 are terminals of coils which are connected internally.

In order to operate a dual voltage motor on the high voltage, the running winding must be connected in series as shown in Figure 36. Leads 2, 3, and 8 are connected and taped, leads 1 and 5 connect together and goes to power. Lead 4 goes to power, see Figure 36..

To operate on the lower voltage, the running windings are connected in parallel. Leads 1, 3, and 5 are connected together, then to power leads 2, 3, 4, and 8 connect together, then on to ground. See Figure 37.

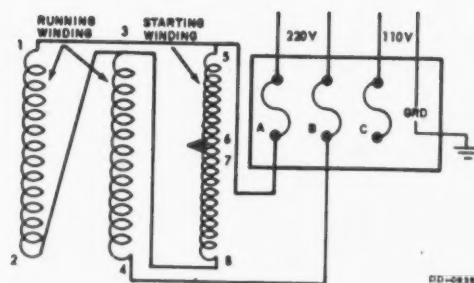


Figure 36 - Schematic of Single-Phase Motor Windings
Connected for High Voltage--220 Volts

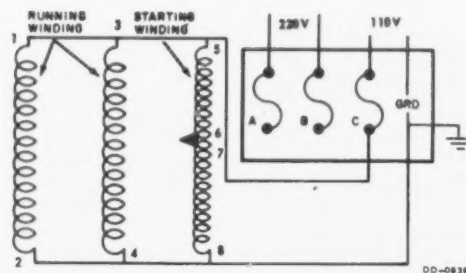


Figure 37. Schematic of Single-Phase Motor Windings
Connected for low Voltage -- 110 Volts

The starting winding is always connected in parallel with the running winding, regardless of which voltage (high or low) is connected to the motor. The starting winding cannot at any time have more than 120 volts across it.

- o How many leads will the single voltage, non-reversible type motor have?

_____.

o How many leads will the single voltage reversible motor have and how are they numbered? _____

_____.

o Explain how to connect the leads, in order to operate a dual voltage motor on the high voltage. _____

_____.

o What is the maximum voltage allowed across the start windings at any given time? _____

f. Read the following paragraphs and answer the questions concerning reversing the rotation of single and three-phase motors.

To determine the direction of rotation of a three-phase motor, it is normally started before the load is connected. If the rotation is incorrect, you can change any two power leads to reverse the rotation of the motor. Figure 38 shows the schematic representation.

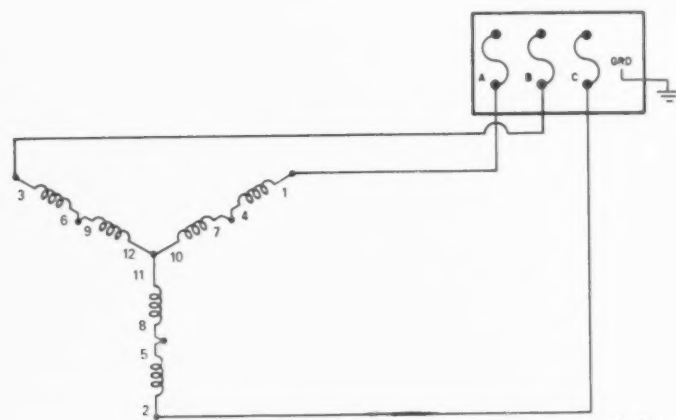
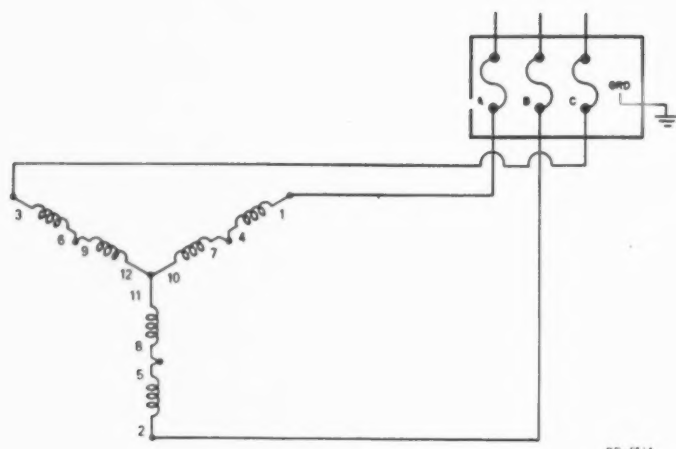


Figure 38. 440-Volt Circuit Diagram for Reversing Direction of Rotation

To reverse direction of rotation of a single-phase induction motor, the start winding leads must be interchanged. Leads 5 and 8 are the start winding leads. High voltage would be leads 2, 3, and 5 connected together and taped. Leads 1 and 8 are connected together, then to power, and lead 4 connects to power. Figure 39 shows these connections. The same method is used for low voltage. Leads 1, 3, and 8 connect to power, and 2, 4, and 5 to ground.

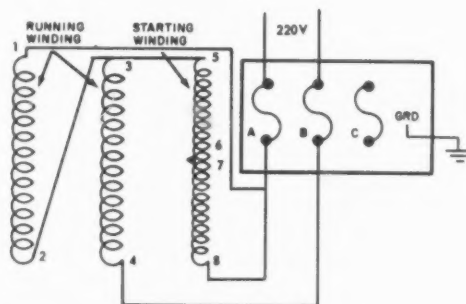


Figure 39. Reversing Direction of Rotation of a single-Phase Motor Connected for High Voltage

o How is the rotation reversed of a three-phase motor? _____

STOP! You have completed the assignment to be accomplished prior to Day 7 class.

Start here for the assignment to be completed prior to Day 8 class.

SERVICING MOTOR STARTERS

a. Read paragraph 12-41 and answer the following questions.

o What sets the limitations in the amount of current that a control contacts can carry safely? _____

o Controls can handle larger motors with the help of what device? _____

o What is a magnetic starter? _____

Magnetic Line Voltage Starter

Electromagnetic energy can be used to close switches. Line voltage starters provide a safe, convenient and economic means for controlling electric motors. They are used to start and stop electric motors. Magnetic line starters are widely used because they are economical and safe and they can also be controlled remotely. They are normally used where full voltage starting torque is needed and where current surge is not a major factor. Magnetic starters may be as simple as the type shown in Figure 40, having only one set of contacts. The contacts called "main contacts" would be connected in series with the conductor carrying power to the motor. When the electromagnetic coil is energized, it sets up a magnetic field attracting the armature. When the armature moves toward the electromagnet, the movable contact (located on the armature) connects with the stationary contact. This completes the circuit to the motor and the motor starts. When the switch in the circuit which supplies power for the electromagnetic coil is opened, the coil is de-energized, causing a loss of the magnetic force. The spring will then pull the contacts apart. This is a simple magnetic line starter. Other magnetic line starters will have more contacts, motor over-current protector relays (heaters), and may depend on gravity to open the contacts. Heaters will be explained later in this study guide. Figure 41 will help you identify the different parts of a magnetic across-the-line starter. This figure shows a three-phase across-the-line starter, containing three sets of main contacts, one set of holding contacts, a coil, two reset contacts, and two heaters. It is designed so gravity will cause the contacts to open when the coil is deenergized. Pressure springs have been added to the contacts to allow them to seat evenly. This prevents bending of the contacts and arcing, thus prolonging their life. Shaded rings are placed on the stationary core to provide a time delay in the loss of flux, thus preventing contact chatter and wear in the moving parts of ac magnetic starters.

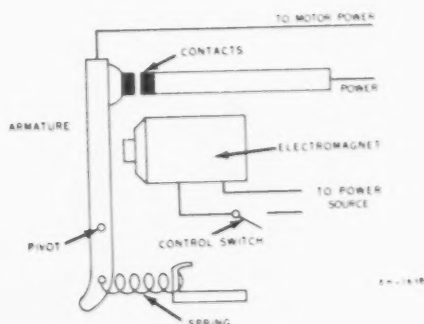


Figure 40. Magnetic Starter

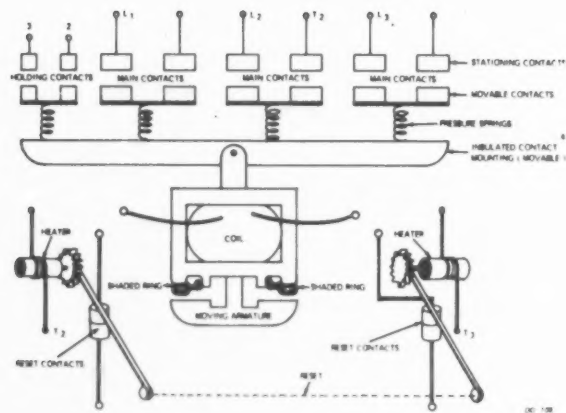


Figure 41. Three-Phase Magnetic Line Voltage Starter

Figure 41 shows how this starter will appear on an electrical diagram. Electrical symbols are used to represent the parts of the starter. Magnetic starters are often called contactors.

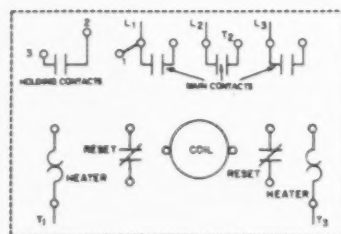


Figure 42. Electrical Diagram of a Magnetic Starter

o What is the purpose of a magnetic line starter? _____

_____.

o How do the main contacts of a line starter connect in a circuit? _____

_____.

o How many sets of contacts does three-phase line starters have? _____

o What is the purpose of the pressure springs in the line starter? _____

_____.

c. Read the following paragraphs and answer the following questions?

Connecting Three- Phase Controllers

Connecting three-phase controllers vary only in the location of the terminals and when the controllers are to serve different duties. Figure 43 shows a square D magnetic starter and a start-stop station controlling a three-phase motor.

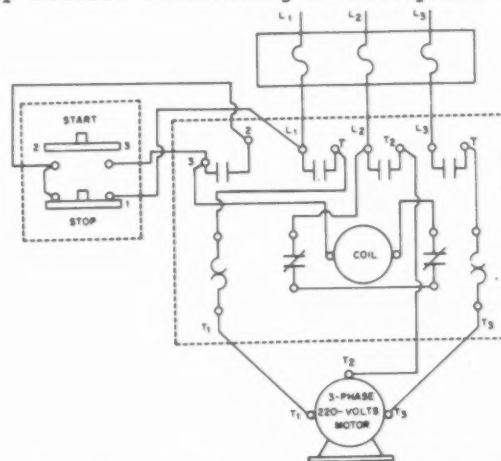


Figure 43. Wiring diagram of a Square-D Magnetic Starter Connected to a Start-Stop Station

Power is supplied to the controller at terminals marked L₁, L₂ and L₃. The motor is connected to three terminals marked T₁, T₂. and T₃. The identification of these terminals will normally be the same regardless of the manufacturer.

In order for the motor to operate, three sets of normally open contacts (main contacts) must close. These contacts are located between the line and the load (L_1 & T_1 , L_2 & T_2 , and L_3 & T_3). To close these contacts, the coil must be energized. This is done through a circuit known as the control circuit. The control circuit runs from terminal L_2 through the two reset contacts (normally closed contacts) through the coil and to terminal three (3) on a set of holding contacts. To have a complete circuit to energize the coil, the control circuit must make connection to L_1 . This point is where the different types of controlling takes place. As in Figure 43, terminal three (3) of the magnetic starter is connected to terminal three (3) of the start-stop station. When the start button is pushed, a circuit is completed from terminal three (3) through the start contacts to terminal two of the start-stop station, through the stop button to terminal one (1) and to terminal L_1 of the magnetic starter. A circuit is now completed between L_1 and L_2 , and the coil becomes energized. When the coil energizes, the armature is lifted causing all normally open contacts to close. The circuit is now complete to the motor. The circuit from terminal three (3) of the magnetic starter to L_1 is known as the start circuit. The start button on a start-stop is a constant pressure switch, meaning it must be held in to keep the contacts closed. If pressure is removed, the circuit would be broken and the coil would become de-energized. To prevent this from happening, another circuit called a holding circuit is added. The holding circuit is connected from terminal two (2) of the magnetic starter to terminal two (2) of the start-stop station. When the coil becomes energized, it closes all normally open contacts, including a set of holding contacts located between terminals two (2) and three (3) of the magnetic starter. When these contacts close, a circuit is completed from terminal three (3) through the holding contacts to terminal two (2), to terminal two (2) of the start-stop station, through the stop button contacts to terminal one (1) to L_1 . When the start button is released, this circuit is used to keep the coil energized. To de-energize the coil, pressure is applied to the stop button which causes its normally closed contacts to open breaking the circuit, de-energizing the coil. Should the motor draw more current than is specified on the data plate, the overcurrent relays will heat and open the normally closed contacts (reset contacts) in the control circuit, which will de-energize the coil. This provides motor protection.

Figure 44 shows a wiring diagram of Arrow-Hart magnetic starter. As you can see, the terminals are marked the same as the Square D, but they are in different locations; even though the wiring remains the same. On some starters, terminals 2 and 3 may be marked C_2 and C_3 .

When a motor system requires controlling from more than one location, additional start-stop stations can be added. Some conveyor belts require this type of control system to allow starting and stopping from either end of the conveyor.

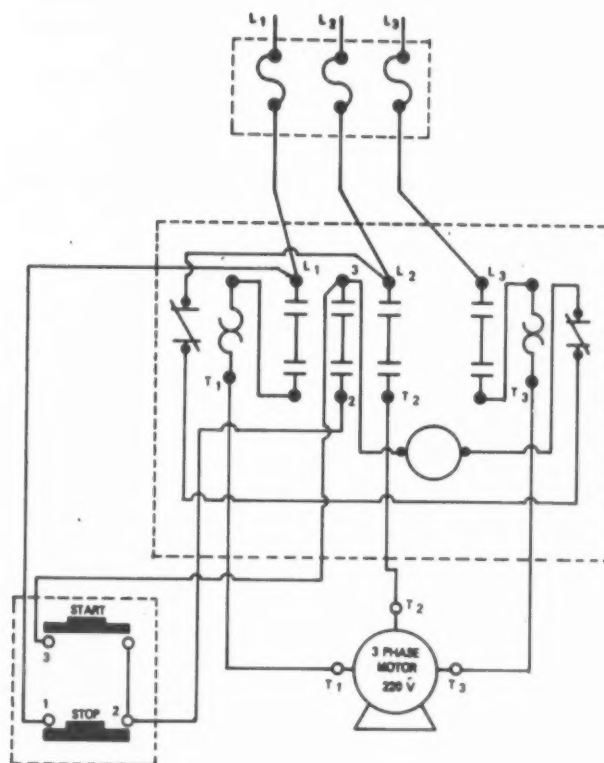


Figure 44. Wiring Diagram of an Arrow-Hart Magnetic Starter
Connected to a Start-Stop Station

o In connecting a three-phase line starter, where is the power supplied to? _____

o Where are the leads from the motor connected? _____

o What occurs when the coil is energized? _____

d. Read the following paragraphs and answer the questions.

Single-Phase Motor Controllers

Single-phase motor controllers are constructed and operate similarly to three-phase motor controllers. Where switching in three conductors is required in three-phase motor systems, only one or two conductors require switching in single-phase motor systems.

Magnetic Line Voltage Starters

Single-phase magnetic starters have the same circuits as the three-phase starters (Power, Control, Load, Start and Holding). They have only two main or load contacts and one overload protective relay. The coil in the starter is usually wound for dual voltage (120/240) and is labeled or color coded. The red lead is the common and is used with either 120 or 240 volt power connections. The white lead is used when low voltage (120 volts) connections are required. The black lead is used when high voltage (240 volts) power is required.

Figure 45 shows a single-phase magnetic starter and motor with low voltage connections.

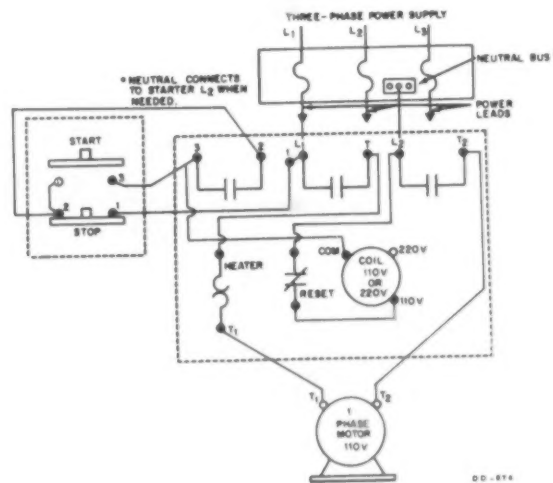


Figure 45. Connecting a Single-Phase Magnetic Starter

o What are the five circuits within the single-phase magnetic starters?

1. _____
2. _____
3. _____
4. _____
5. _____

o How many contacts does a single-phase line starter have? _____

e. Read the following paragraphs and answer the questions.

Maintenance of Motor Starters

The most frequent trouble encountered with motor starters is contact trouble. Contacts should be inspected for excessive burning or pitting and for proper alignment. If they are pitted, copper contacts may be filed, but care must be exercised not to remove too much contact surface or to change their shape appreciably. Copper contacts are subject to heat and oxygen on closing and opening of the circuit, and copper oxide may be formed on the surface of the contact. This oxide is an insulator which must be removed if it covers a large part of the contact surface. Most contacts made of copper are arranged to be of the wiping type, which allows the mechanical closing of the contacts to remove this oxide as it forms. If the contacts are silverplated, the silver oxide is a good conductor and need not be removed; in fact, silver contacts should never be filed. The contacts should be inspected not only for pitting but for proper alignment and for proper contact pressure. Improper alignment or lack of contact pressure will cause excessive arcing and pitting of the contacts.

General Procedure

The first procedure in any organized maintenance of equipment should be periodic inspection to prevent serious trouble from arising. This inspection should include not only electrical equipment but the machine as well, should point up the wear and tear on the electrical equipment, and should provide a basis on which replacement of parts and correction of danger spots can be taken care of before they cause serious trouble.

One of the greatest causes of failure of control systems is the presence of dust, grease, oil, and dirt, which must be removed periodically in order that the equipment may function properly. The removal of dust and dirt may be accomplished by dusting or wiping with rags, but this is not always effective with oil and grease. These substances generally should be removed by the use of a solvent such as carbon tetrachloride. Care should be exercised whenever these solvents are used, because the inhaling of any appreciable quantity of their fumes is quite likely to be very harmful. Therefore, adequate ventilation should always be provided.

Periodic inspection should always include a check for overheating of electrical equipment and mechanical parts, because excess heat is always an indication of trouble to come. The value of checking for excess heat depends upon your knowledge of the proper operating temperature of coils, contacts, transformers, and the many other pieces of equipment associated with machinery, motors, and control.

Another frequent cause of failure of control equipment is electrical connections. Each connection should be periodically checked for tightness, and the inspection should include the checking of possible loose bolts and nuts on the equipment.

Short circuits and grounds in the electrical wiring may be prevented by proper inspection of insulation and by using a Megger insulation tester on motors and cables in associated equipment.

If you are to maintain the same equipment over a period of time, the first law to follow is to be familiar with your equipment. Know your equipment mechanically and electrically so that you will sense trouble before it develops.

The second law is to be observant. Whenever you pass a piece of equipment for which you are responsible, listen and look. Quite often this is all that is necessary to tell you that trouble is on its way. Good maintenance procedure can be summed up in a very few words: Keep it tight, keep it clean, keep it lubricated, and inspect it frequently.

Should the contactor be equipped with flexible leads, they should be checked for fraying and broken strands and should be replaced if these conditions exist. Should the starter be equipped with arc shields, they should be inspected for proper alignment around the contacts. They should be checked for accumulations of dust and dirt, and if carbon deposits have built up on the inside of these shields, these deposits should be carefully removed, since carbon reduces the arc path and can be the cause of serious arc overs, particularly under high-voltage conditions.

Spring tension for proper contact pressure is very important in a starter and should be checked against manufacturer's standards if they are available. They should at least be checked to see that each contact has approximately the same spring tension so that the contact pressure will be equal on each contact. Improper or unequal spring tension is one of the most common causes of contact chatter and starter hum, so be sure that when these conditions exist, you check the spring tension on every contact to determine if it is sufficient and that they are all equal.

- o What is the most frequent trouble encountered with motor starters?

- o What is the first procedure in any organized maintenance of equipment?

- o How can good maintenance procedures be summed up? _____

TYPES AND FUNCTIONS OF ELECTRICAL OVERLOAD PROTECTOR.

a. Read the following paragraphs and be prepared to discuss the material in class.

Overload Protection

Electric motors require overload protection to prevent burnout. If permitted, electric motors will operate at a higher current than their rated capacity. This may be caused by low line voltage, by an open line in a three-phase system, and by an overload of the driven machinery. The overload on an electric motor causes it to draw excessive current that causes overheating. The overheating will eventually result in a burnout. To prevent this, overload relays are employed on a starter to limit the amount of current a motor can draw. This is overload protection, or running protection. An overload relay consists of a current sensitive element and a set of normally closed reset contacts. The overload relays of a starter function to protect a motor from excessive current that is destructive to motors. Current sensitive (thermal or magnetic) elements of overload relays are connected either directly or indirectly in the motor lines through current transformers. The overload relays act to de-energize the starter and stop the motor when excessive current is drawn.

Thermal Cutouts

Thermal cutouts are usually of the bimetallic or melting alloy types. The bimetallic type is constructed of two dissimilar metals which, when heated, bend due to the different rate of expansion of the two metals. A heating element in the motor line circuit generates the heat necessary to activate the strip. Current in excess of the desired amount causes deflection of the bimetallic strip to the extent that the contacts spring apart, thus opening the holding coil circuit as shown in Figure 46. A reset button is depressed to reactivate the mechanism when the strip has cooled to operating tolerance.

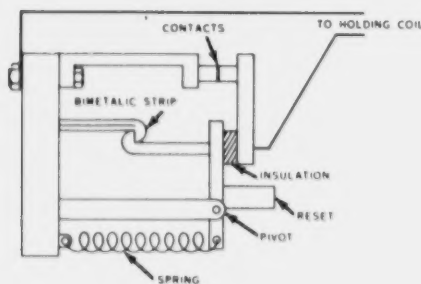


Figure 46. Bimetallic Overload Relay

The melting alloy overload relay employs a heating coil connected in the motor line circuit. See Figure 47.

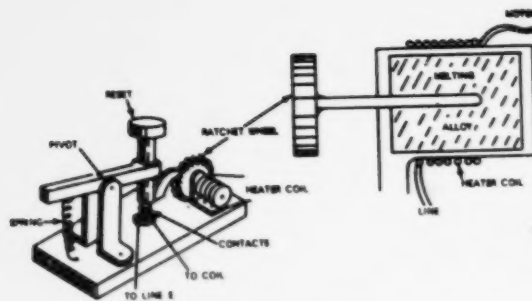


Figure 47. Melting Alloy Thermal Overload Relay

The heat caused by excessive current in the motor circuit melts the metal alloy (similar to solder) releasing the spring-loaded shaft. The shaft is then capable of turning which permits the reset contacts to open, thereby disrupting service to the motor. When the alloy has cooled and solidified sufficiently, the motor may be restarted by depressing the reset button. A laboratory example of the melting alloy principle is shown in the figure.

The main advantage of the melting alloy over the bimetallic type is its amperage rating doesn't vary after repeated heatings.

Magnetic Overloads

The magnetic overload relay consists of a coil, a plunger, a dashpot, and a set of contacts. See figure 48. The coil is connected in series with the motor. When a determined amount of current passes through the coil, the magnetic field will pull the plunger up causing the contacts to open. By adjusting the length of the plunger, the amount of current required to pull the plunger up can be varied. An oil-filled dashpot added to provide a time delay. A plate on the bottom of the plunger is submerged in the oil and acts as a piston. The plate has holes in it that can be adjusted in size to change the time delay. When the coil pulls the plunger up, the oil must flow through the hole in the plate as the plunger rises. By changing the size of the hole, the time delay can be increased or decreased. Quick tripping is obtained through the use of a light grade dashpot oil.

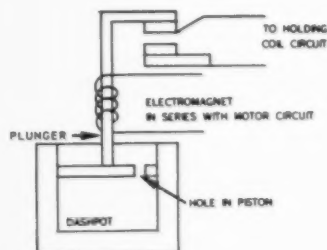


Figure 48. Magnetic Overload Relay

Selecting Heaters

The overload relay size is determined by the full load current of the motor it protects. When selecting the heaters to protect a motor, you should check the motor data plate to find the full load current. Each manufacturer normally puts a heater selection table in the controller cover. Heaters are not identified by amperage, but by the manufacturer's catalog number. By using the full load current of the motor to be protected and referring to the manufacturer's table, the proper heater can be selected. Figure 49 is a Cutler-Hammer heater table. If the full load current of a 2 hp motor at 230V is 6.8 amps, the heater required would be an H1033.

HEATER COIL SELECTION TABLES

For Size 1 Starter				For Size 2 Starter		For Size 3 Starter		For Size 4 Starter	
Ampere Range	Catalog No.	Ampere Range	Catalog No.	Ampere Range	Catalog No.	Ampere Range	Catalog No.	Ampere Range	Catalog No.
.157-.177	H1101	2.20-2.45	H1024	3.89-4.35	H1028	8.72-9.67	H1035	19.5-21.9	H1042
.178-.198	H1102	2.46-2.74	H1025	4.36-4.81	H1029	9.68-10.8	H1036	22.0-24.7	H1043
.199-.223	H1103	2.75-3.07	H1026	4.82-5.35	H1030	10.9-12.0	H1037	24.8-29.0	H1044
.224-.249	H1104	3.08-3.42	H1026	5.36-5.96	H1031	12.1-13.5	H1038	29.1-31.9	H1045
.250-.280	H1105	3.43-3.81	H1027	5.97-6.63	H1032	13.6-15.0	H1039	32.0-36.1	H1046
.281-.313	H1106	3.82-4.27	H1028	6.64-7.41	H1033	15.1-16.8	H1040	36.2-40.7	H1047
.314-.353	H1107	4.28-4.71	H1029	7.42-8.23	H1034	16.9-19.1	H1041	40.8-46.2	H1048
.354-.395	H1108	4.72-5.24	H1030	8.24-9.19	H1035	19.2-21.6	H1042	46.3-52.4	H1049
.396-.445	H1109	5.25-5.87	H1031	9.20-10.2	H1036	21.7-24.5	H1043	52.5-59.2	H1050
.446-.499	H1110	5.88-6.48	H1032	10.3-11.4	H1037	24.6-27.8	H1044	59.3-66.3	H1051
.500-.562	H1111	6.49-7.27	H1033	11.5-12.8	H1038	27.9-31.5	H1045	66.4-75.1	H1052
.563-.631	H1112	7.28-8.14	H1034	12.9-14.1	H1039	31.6-35.5	H1046	75.2-87.1	H1054
.632-.711	H1113	8.15-9.03	H1035	14.2-15.9	H1040	35.6-40.3	H1047	87.2-99.9	H1055
.712-.799	H1114	9.04-10.0	H1036	16.0-18.1	H1041	40.4-45.6	H1048	100.-113.	H1056
.800-.903	H1115	10.1-11.2	H1037	18.2-20.4	H1042	45.7-51.8	H1049	114.-129.	H1057
.904-1.01	H1116	11.3-12.5	H1038	20.5-23.3	H1043	51.9-58.6	H1050	130.-135.	H1058
1.02-1.13	H1117	12.6-13.8	H1039	23.4-26.5	H1044	58.7-65.2	H1051	-----	-----
1.14-1.27	H1018	13.9-15.6	H1040	26.6-30.3	H1045	65.3-74.3	H1052	-----	-----
1.28-1.43	H1019	15.7-17.7	H1041	30.4-34.7	H1046	74.4-86.3	H1054	-----	-----
1.44-1.60	H1020	17.8-19.9	H1042	34.8-39.6	H1047	86.4-99.0	H1055	-----	-----
1.61-1.79	H1021	20.0-22.5	H1043	39.7-45.0	H1048	-----	-----	-----	-----
1.80-1.98	H1022	22.6-25.3	H1044	-----	-----	-----	-----	-----	-----
1.99-2.19	H1023	25.4-27.0	H1045	-----	-----	-----	-----	-----	-----

Figure 49. Heater Table

b. Read paragraphs 7-28 and 8-22 in the Modern Refrigeration textbook. Be prepared to discuss and answer questions in class over the assigned material.

SCHEMATIC INTERPRETATION AND ELECTRICAL TROUBLESHOOTING

OBJECTIVE

To help you learn to interpret schematic diagrams and to perform electrical troubleshooting.

INTRODUCTION

This studyguide/workbook will prepare you for the instruction to be conducted in days 8, 9 and 10. You must accomplish the sections assigned for each day and be prepared for a test over the material when you come to class.

INFORMATION

Read the following paragraphs and answer the questions.

At first glance, a detailed wiring diagram may seem difficult to understand. It may help to think of a wiring diagram as a type of road map. You should have some kind of idea of where you are and where you want to go. It would be foolish to study a road map of California if you were planning a trip in Texas. The same is true of wiring diagrams. Identify the area that immediately concerns you. It is unlikely that you will need to consider more than one circuit at a time.

- o When studying a wire diagram it may help to think of it as a type of _____.

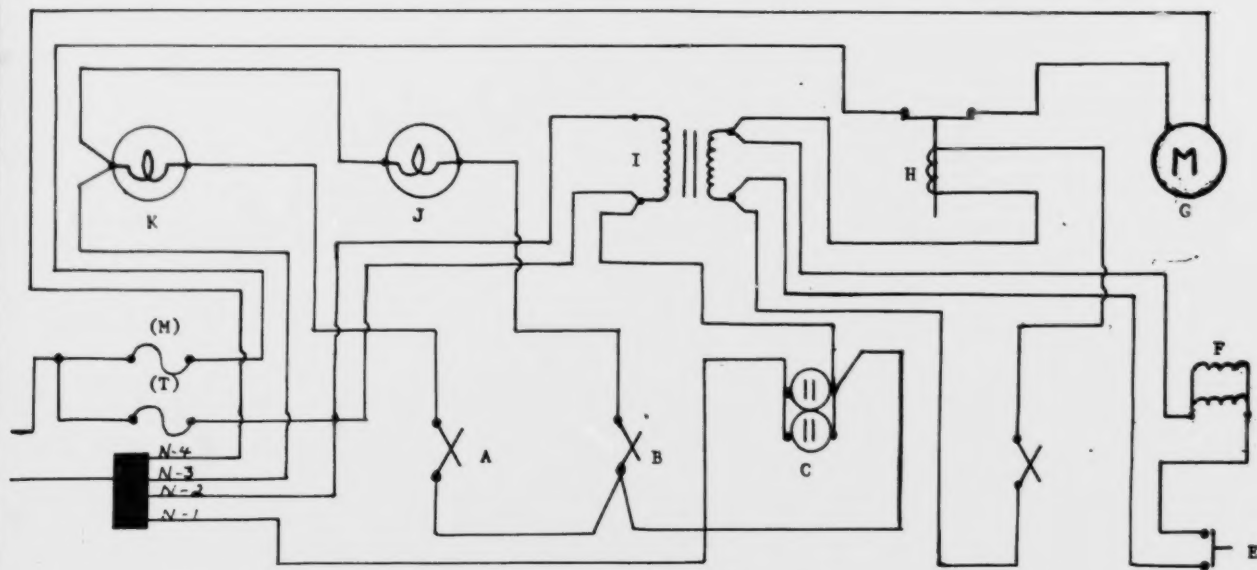
Observe Figure 50. Probably the first thing you would need to know about any electrical circuit is if it has power to the circuit. Let's look at the power source as indicated on the left side of the drawing. A voltmeter check at the power source will show if the system is receiving proper voltage (120 volts).

- o What is the first thing you would need to know about an electric circuit?

- o The supply voltage for Figure 50 is _____ volts.

Read the paragraph below and answer the following questions.

Now let us look at the lighting circuit. What type of circuit is it? It has more than one path for current to flow with one unit of resistance in each path, so it must be a parallel circuit. In tracing any circuit, the best place to start is at the power source. Usually the negative side of the power source is used. It should be determined if the circuit is drawn "Power On" or "Power Off". A circuit that is drawn "Power On" will show the relay contacts in the position they will normally be when the circuit is operating. Figure A is drawn with the "Power On". If the circuit is drawn with the "Power Off" it may be necessary to change the circuit as you trace current flow. Sometimes you may desire to use colored pencils to trace out circuits.



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Figure 50. Lighting Circuit

- o Where is the best place to start tracing a circuit?

o When tracing a circuit should you start at the positive or negative side of power? _____.

- o Figure A is drawn with the "Power _____".

- o When the circuit is drawn with the "Power Off" it may be necessary to _____ the circuit as you trace it.

Read the paragraph below and answer the following questions.

Let's take a look at figure A again. We have already determined that the circuit is drawn with "Power On". Now let's trace the current flow through the various components. First we'll trace current flow through the receptacle C. Starting at neutral N1 we see that the current will flow first to the receptacle, then bypass the transformer I and on to Fuse (T). That is the complete circuit for receptacle C.

- o The voltage at receptacle C is _____ volts.

Read the paragraph below and answer the following questions.

The next circuit we'll trace out is for transformer I. Begin at N2 and trace the current flow through the primary coil of transformer I and back to fuse (T). This is the circuit for the primary coil of transformer I. If we take a closer look at transformer I we'll see that it is a step-down transformer. The voltage is stepped down to 24 volts in the secondary coil. This secondary coil supplies power for components F and H. By starting at the bottom of the secondary coil we can trace current flow through push button switch E to buzzer F and back to the secondary coil. When pushbutton E is pressed it completes the circuit and buzzer F operates.

Starting once again at the bottom of the secondary coil we can trace current flow through switch D to the coil in relay H. When switch D is closed the coil in relay H energizes closing the contacts in the motor circuit. The current then flows back to the secondary coil. Since there are two paths for current to flow with, one unit of resistance in each path, we can say that buzzer F and relay H are in parallel.

- o Transformer I steps down voltage from 120 volts to _____ volts.
- o Since buzzer F and relay H are in parallel, we can say both components operate at _____ volts.

Read the paragraph below and answer the following questions.

Now let's take a look at lights J and K. If we start by tracing our circuit from N3, we can trace our current flow to light K. Here our current branches off and flows through both lights J and K. Current will flow through light J to switch B and also through Light K to switch A. Both circuits tie in at switch B and current flows on past receptacle C and transformer I to fuse (T). Switches A and B control the lights. Switch A controls light K and switch B controls light J. If we take another look at the circuit, we can see that we have two complete paths for current to flow with one unit of resistance in each path. Therefore, we can say lights J and K are in parallel.

- o Which light does switch A control? _____.
- o The voltage for lights J and K is _____.

Read the paragraph and answer the following question.

The last component to trace current flow through in this diagram is the motor. If we begin tracing our current flow at N4, we can see that our current will flow first to our motor G and then on through the contacts of Relay H. (Remember that the contacts in the relay close when the coil is energized by closing switch D.) From relay H our current flows to fuse (M). That is our complete circuit for Motor G.

o Which component does switch D control to operate the motor.

Though figure A may have seemed complicated at first, by breaking it down and tracing out the separate components, we greatly simplified it. In time, with practice and patience, you will be able to interpret schematic diagrams with little difficulty.

STOP! You have completed the assignment to be accomplished prior to Day 8 class.

Accomplish the following assignment prior to Day 9 class.

TROUBLESHOOTING ELECTRICAL CIRCUITS

Read the following paragraphs and answer the questions.

Trouble with a refrigeration unit often involves electrical problems. The refrigeration technician should be able to troubleshoot electrical circuits. Trying to correct electrical troubles before knowing the type and location is a waste of time and effort. The efficient troubleshooter analyzes the symptoms first and then locates the trouble before any corrective action is taken.

Electrical troubleshooting is a systematic process of analyzing, locating, and correcting electrical troubles. The fundamental steps of electrical troubleshooting are:

- o Perform Operational Check
- o Determine type of trouble
- o Locate Trouble
- o Perform corrective action

A wiring diagram of the electrical system that is being worked on should be obtained so that the types of circuits and units involved can be understood. A picture of the circuit will aid in troubleshooting and making operational checks of the units.

- o Define troubleshooting. _____

- o The fundamental steps of electrical troubleshooting are: _____

1. _____
2. _____
3. _____
4. _____

Read the following paragraphs and answer the questions.

Types of Troubles

An important fact to remember is that there are only three types of troubles: OPENS, SHORTS, and LOW POWER.

OPENS

An open circuit is one that has a break somewhere in it. This break could be located in the wire, in the switch, fuse, or in the unit of resistance. In fact, it could exist anywhere. In order to have current flow, you must have a complete path or continuous circuit.

Naturally, if there is a break or open in the circuit there can be no current flow; therefore, the unit or resistance would not operate, see figure .

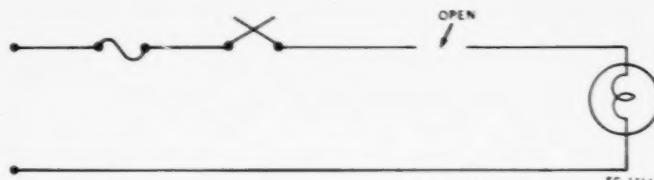


Figure 51. Open Wire

There are three different meters that can be used to locate an open. These are the Voltmeter, Ohmmeter, and Continuity Tester.

- o The three types of troubles are:
 1. _____
 2. _____
 3. _____
- o An open circuit is one that has a _____ in it.
- o Will there be current flow if there is an open in the circuit? _____.
- o List the meters used to locate opens.
 1. _____
 2. _____
 3. _____

Read the following paragraphs and answer the questions

Locating Opens

The next location of an open can be found by using the voltmeter. You should first of all understand what a voltmeter indicates in a normal operating circuit. Figure _____ illustrates normal voltmeter readings throughout the circuit.

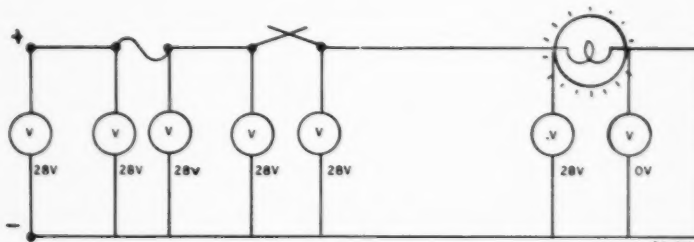


Figure 52. Normal Voltmeter Readings

A voltmeter connected positive to negative should always indicate the difference in voltage across the two points. A voltmeter connected negative-to-negative or positive-to-positive should not give a difference in electrical pressure, see Figure 53. The last voltmeter in Figure 53 connected negative-to-negative and therefore is reading 0 volts. Readings other than these are considered abnormal. Exact location of an open can be found in the positive or negative parts of the circuit between a normal and an abnormal reading.

o A voltmeter connected positive-to-positive will read _____ volts.

Read the following paragraphs and answer the questions.

Figure 53 illustrates a voltmeter being used to find an open in wire A-4. The open is located between the last point of source voltage and the first point of zero voltage. In Figure 53 the last point of source voltage (28 volts) and the first point of zero voltage (0 volts) is at A-4. Therefore, the open is at A-4.

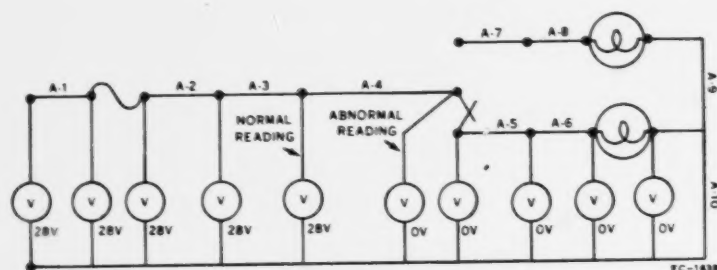


Figure 53. Locating an Open in Wire A-4

In Figure 54, a voltmeter is being used to locate an open in the circuit.

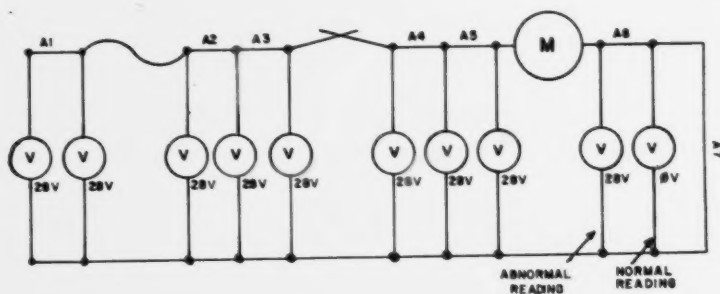
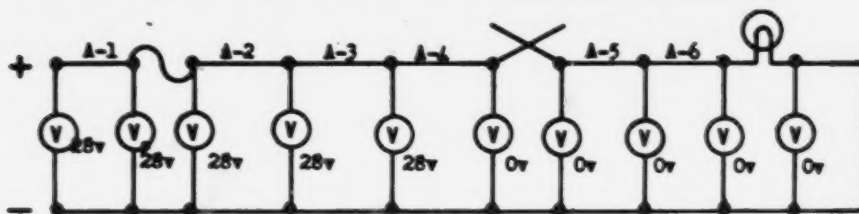


Figure 54. Locating an Open Wire A-6

The exact location is wire A-6.

Study the illustration and complete the sentences below.



The open is located in wire A - _____.

With one meter lead on wire A-1 and the other on wire A-6, the meter will indicate _____ volts.
Zero/28

With one meter lead on wire A-1 and the other on wire A-3, the meter will indicate _____ volts.
Zero/28

Read the following paragraphs and answer the questions.

Opens can also be found by using an ohmmeter or a continuity meter. POWER MUST BE OFF and the circuit ISOLATED when using these meters. In Figure 55, an ohmmeter is being used to locate an open in wire A-6.

(Note: The fuse has been removed to isolate the circuit.)

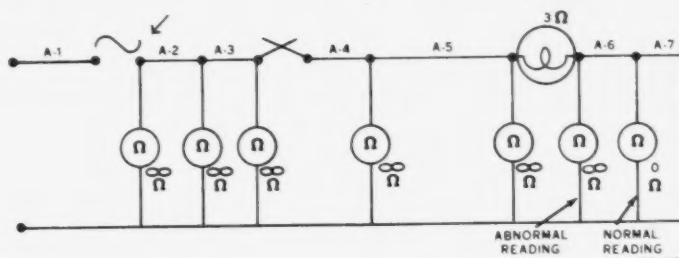


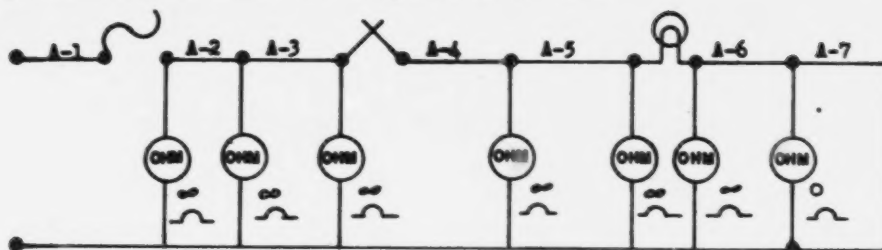
Figure 55. Locating an Open with an Ohmmeter

CAUTION: Connecting an ohmmeter to a live circuit will damage the ohmmeter.

In Figure 55, you will notice that the ohmmeter does not register continuity all the way through the circuit. The open is found between the first continuity reading (0Ω) and the last infinity reading (∞).

The ohmmeter indicates continuity (uninterrupted good connection) when registering zero ohms (0Ω) and infinity (∞ unmeasurable) when circuit is open.

Study illustration below and complete sentences.



The open is located in wire A - _____.

With one meter lead on wire A-2 and the other lead on wire A-5, the meter will indicate _____ ohms.

With one meter lead on wire A-2 and the other on wire A-7, the meter will indicate _____ ohms.

While using an ohmmeter the power must always be _____.

While using a voltmeter the power must always be _____.

Read the following paragraphs and answer the questions.

SHORTS

A short means that there is contact where there should not be contact; consequently, there is current flow where there should not be current flow. Indications of shorts are units operating that should not be operating, blown fuses and tripped circuit breakers.

DIRECT SHORT

In the case of a direct short, a negative lead is in contact with a positive lead, by passing the unit of resistance.

From Figure 56 you can see that current in this situation will take the path of least resistance. The excessive current flow will cause the fuse to blow, or if the protective device happens to be a circuit breaker will trip, opening the circuit.

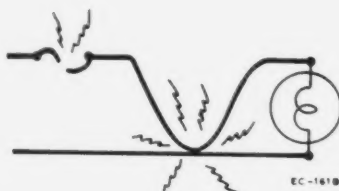


Figure 56. Direct Short

- o What is a direct short? _____
- _____
- _____
- _____

Read the following paragraph and answer the questions.

Locating Direct Shorts

Some kind of a continuity test, such as with an ohmmeter, should be used in locating direct shorts. The positive leads should be isolated and the testing devices connected across the isolated leads. Notice in Figure 57, an ohmmeter is being used to locate contact between isolated positive leads and the negative lead. Only the ohmmeter connected to A-4 lead indicates continuity (0); therefore, a-4 lead must be touching the negative side of the circuit, providing a shortcut for current to flow.

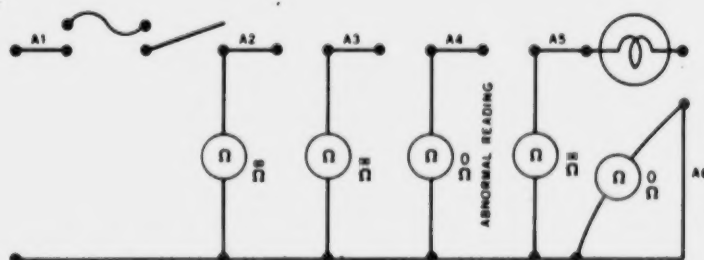


Figure 57. Locating a Direct Short

- o What type of meter is used to locate direct shorts? _____.

Read the following paragraphs and answer the questions

Cross Shorts

Where as, the direct short is contact between the positive lead of a circuit and the negative lead of a circuit, the cross short is caused by the positive leads on independent circuits coming in contact with each other. In other words a positive from one circuit touching a positive in another circuit.

During an operational check, a cross short is indicated by two independent units operating from the same switch. In Figure 58, positive lead A-8 is touching positive lead A-3. Even though the switch which controls L_2 is open, there is a complete path for current flow from A-8 to A-1; consequently L_2 burns.

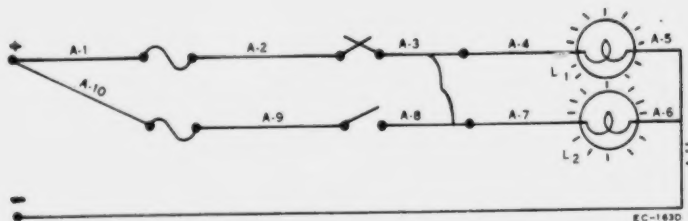


Figure 58. Cross short

- o What causes a cross short? _____
- o What is an indication of a cross short? _____

Read the following paragraphs and answer the questions.

Locating Cross Shorts

The same testing devices and procedures are used in locating cross shorts as were used in locating direct shorts. Power must be off and the positive leads of both circuits isolated, see Figure 59.

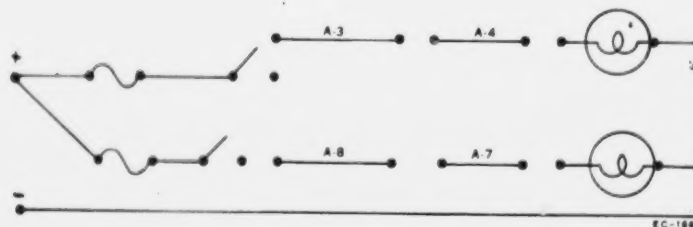


Figure 59. Leads Isolated

After both circuits are isolated, the test meter is connected across the probable leads, such as A-3 to A-7, A-3 to A-8, A-4 to A-8, or A-4 to A-7. Note that any of these combinations would have the same effect. In Figure 60, the ohmmeter shows the cross short to be between A-3 and A-8. In other words, the meter shows continuity between the two isolated leads (A-3 and A-8) where there should NOT be continuity. This means these two positive leads are making contact.

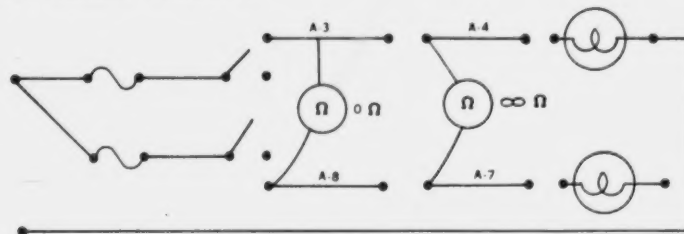


Figure 60. Locating a Cross Short

o To locate a cross short, power must be _____ and the positive leads of both circuits.

o Should there be continuity between two isolated positive leads when checking for a cross short.

Read the following paragraphs and answer the questions

Low Power

This condition is often found in old buildings or in areas where the electrical load has been increased without increasing the size or number of electrical circuits. A low power condition is indicated by dim lights, relay chatter, and sluggish motors.

If a low power condition is suspected, all the electrical units on the circuit should be turned on. This should create maximum current flow. Voltage drops across the units should be compared with total voltage available. Figure 61 shows a line loss check. Here our motor has 90 volts where it should actually be 110 volts. There is a low power condition in this circuit.

If a low power condition is suspected, all the electrical units on the circuit should be turned on. This should create maximum current flow. Voltage drops across the units should be compared with total voltage available. Figure 61 shows a line loss check. Here our motor has 90 volts where it should actually be 110 volts. There is a low power condition in this circuit.

If a low power condition is discovered, the electrical lead must be reduced or a new circuit installed.

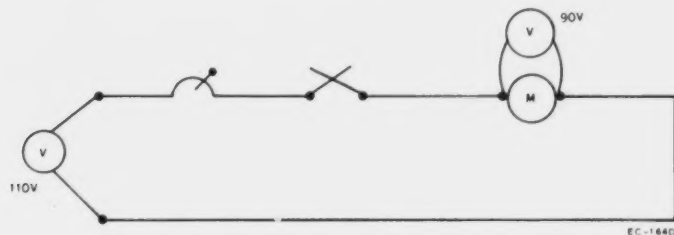


Figure 61. Voltage Drops Should Equal Total Voltage

o Where are low power conditions often found? _____

o List the indications of low power?

1. _____

2. _____

3. _____

o What should you do if a low power condition is suspected? _____

o If a low power condition is discovered what should be done? _____

Read the following paragraph and answer the questions.

Shorted Switches

Another type of trouble that is common in electrical circuits is shorted switches. A shorted switch is one that fails to break contact when it is placed in the OFF position. The effect of a shorted switch is that the unit operates continuously. Any test meter can be used to determine whether the switch is defective. In Figure 62, an ohmmeter indicates that the switch is shorted.

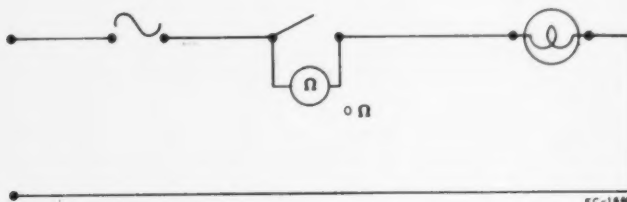


Figure 62. Checking for a Shorted Switch

o Define a shorted switch. _____

o What is the effect of a switch? _____

Read the following paragraphs and answer the questions.

Safety Precautions

The first thing a technician should always think about is safety. Working safely implies several things:

- o Safety to the service technician
- o Safe handling of tools instruments and equipment.

Since refrigeration and air conditioning units are usually motor driven, electrical supply to the system presents some hazard. If electrical circuits are not properly insulated and handle, it is possible for the operator to receive a dangerous electrical shock.

Always disconnect the power or make sure all electrical components are safe before beginning on a job. An electrical short across a watch or ring can cause a severe burn. It is best to remove watches and rings when working on electrical equipment.

Be sure to use all safety precautions when using test equipment. Improper usage can cause damage to the meters and possible injury to the service technician.

o What should you do before working on a unit? _____

o Why should you remove watches and rings before working on electrical units?

STOP! You have completed the assignment to be accomplished prior to Day 9 class.

Accomplish the following assignment prior to day 10 class.

ISOLATION PRODECURES IN TROUBLESHOOTING

Read the following paragraphs and answer the questions.

We have already learned that troubleshooting is a systematic process of analyzing, locating, and correcting electrical troubles. When troubleshooting a circuit, the service technician must be able to locate the problem and isolate it down to the smallest component. Knowing the circuit symptoms that each type of trouble indicates will aid you greatly in the location and repair of the malfunction. Location of the exact place in the circuit that is causing the malfunction usually requires some type of test equipment. You should first identify the type of electrical trouble, and then select the correct test equipment to locate the exact wire or unit causing the trouble. It should then be an easy matter to repair the trouble.

o A service technician must be able to locate a problem and _____ it down to the smallest component.

o The first thing a service technician should do is _____ the type of electrical problem.

Isolation of Electrical Troubles

Read the following paragraphs and answer the questions.

Look at Figure 63 and note that five individual troubles are indicated. We will consider them one at a time. The trouble indication will be stated, an analysis will be given, the meter readings discussed and the trouble identified for each of the five troubles.

Trouble number one was indicated by an inoperative motor. A visual check showed that our relay was still operating. Since no power was reaching the motor, an open circuit is indicated. When a voltmeter was placed across the fuse at the power source, the voltmeter read 120 volts. Normally, a fuse does not offer resistance to a circuit and therefore should not cause a voltage drop. Since this fuse is using all the voltage in the circuit, it must be open. When the fuse is replaced, the circuit operates normally.

o What was the indication for trouble number one? _____

o Should there be a voltage drop at the fuse? _____

Read the following paragraphs and answer the questions.

Trouble number two is indicated by no alternating current to the system (nothing works). This also indicates an open circuit. By looking at the diagram we see that only lines that could affect the circuit in this manner are the main hot and neutral lines. If we check the hot line, we find that there are no problems but the neutral line shows a voltage drop of 120 volts. The neutral line is not a unit of resistance and should not cause a voltage drop. Since the neutral line is using all the voltage, it must be open. When this line is replaced, the circuit operates normally.

o What was the indication for troubles number two? _____

o A voltmeter placed negative to negative should get a reading of _____ volts.

Read the following paragraph and answers the question.

Trouble number three is indicated by light J being continuously lit. Placing switch B in the OFF position does not turn out the light. This indicates that switch B is shorted. By turning off the power and unscrewing the light bulb to isolate the circuit, we can use an ohmmeter to check the switch. The ohmmeter shows continuity through the switch in both the ON and OFF position. This indicates that the switch is shorted. When the switch is replaced the circuit resumes normal operation.

- o A switch which fails to break contact is known as a _____ switch.

Read the following paragraph and answer the questions.

Trouble number four is indicated by an inoperative motor G. Further investigation reveals that relay H is not operating, consequently the contacts are not completing the motor circuit and motor G will not operate. This indicates an open in the relay circuit. By turning off the power and checking the circuit with an ohmmeter, we find that there is no continuity in the coil. This means that there is an open in the coil and the relay must be replaced. When the relay is replaced, the circuit resumes normal operation.

- o Why wouldn't motor G work? _____

_____.

- o How was trouble four repaired? _____

_____.

Read the following paragraph and answer the question.

Trouble number five is indicated by light K being inoperative. A meter check at switch A reveals the switch to be good. By checking light K with a voltmeter, we find that we have 120 volts applied. This indicates that we have an open in light K. When the light is replaced, the circuit operates normally.

- o What is the indication for trouble number five? _____

_____.

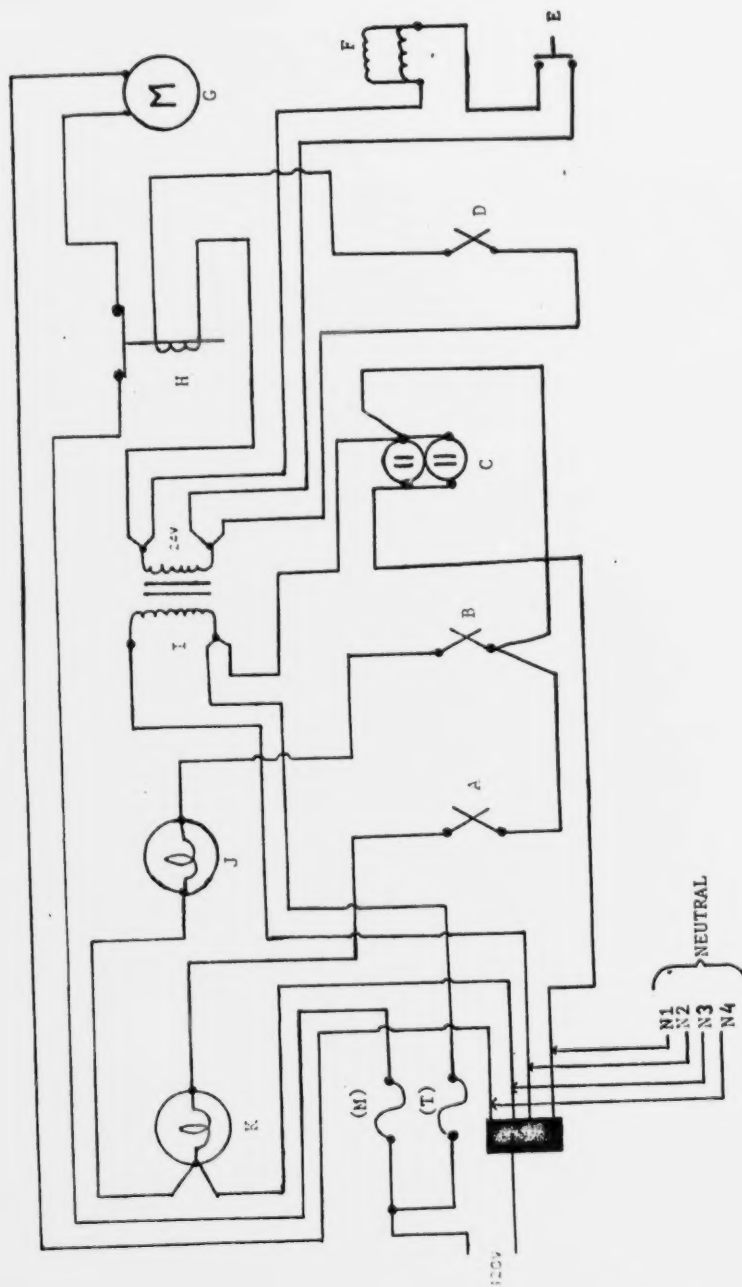


Figure 63. Electrical Troubles

7-17

Study Figure 64 and read the indications for each trouble then answer the following questions.

Trouble number one was indicted by condensation and frost around freezer door. This indicates a problem with the Mullion Drier Circuit. A check with an ohmmeter shows no continuity through the heater.

o What is the trouble? _____

o What must be done to correct this problem? _____

o Could this problem have been found by using a voltmeter? _____

Trouble number two was indicted by the unit running all the time. A check with an ohmmeter shows that the thermostat has continuity whether it is ON or OFF.

o What is the problem? _____

o How can this problem be corrected? _____

Trouble number three is indicated by an inoperative fan motor. By checking the motor we find that we have no power applied to it. A voltmeter check between the motor and the switch gives us a reading of 120 volts.

o What is the trouble? _____

o How can this problem be corrected? _____

Trouble number four is indicated by the whole system being inoperative. This problem indicates an open circuit. A voltmeter check shows a reading of 120 volts across the fuse.

o Should there be a voltage drop across the fuse? _____

o What is the trouble? _____

o How can this problem be corrected? _____

Trouble number five is indicated by the compressor motor not operating. A continuity check shows that the compressor is good. By checking the relay we find that we have no continuity through the coil.

- o Should the relay coil have continuity? _____.
 - o What is the trouble? _____
-
-
- o What component must be replaced to make the unit operate? _____
-

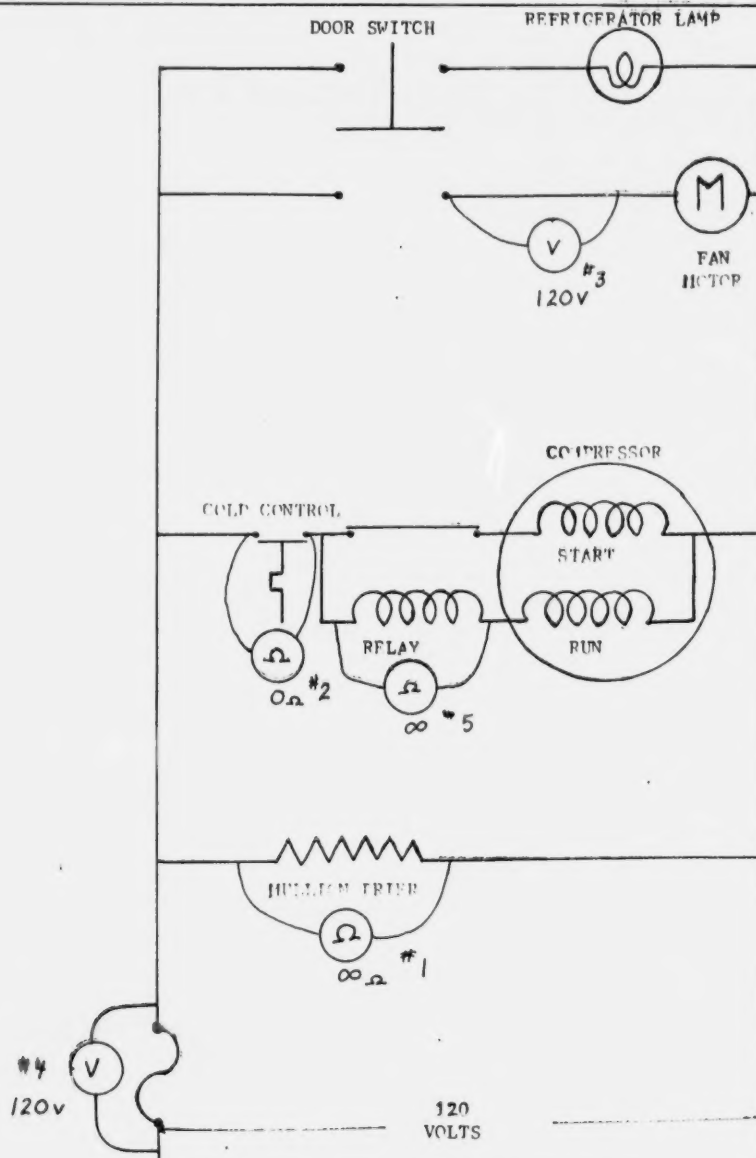


Figure 64. Electrical Troubles

Read the following paragraphs and answer the question.

Replacement Procedures

Once a unit or component has been identified as the source of trouble, it is necessary to replace the malfunctioning part. It will be necessary to identify exactly the unit that you are replacing. Components can look alike without operating the same.

Once you have obtained the exact replacement part, you are ready to start your replacement. You should first make a sketch of the installed unit prior to removing it. Identify the conductor terminals by color, number, and location on the unit. Check the position of the installed unit since it is possible in some cases for part of the operation to rely on gravity, as in motor starters and some relays.

- o It is necessary to _____ the unit you are replacing.
- o Before removing the component you should make a _____ of how it is connected.
- o Why is it necessary to notice the position of some components before replacing them? _____

Read the following paragraph and answer the question.

Be sure to shut off all electrical power and tag the circuit breaker that controls electrical power to the unit to stop anyone from turning the power on to the circuit while your working on it. It may be necessary to shut off and bleed down pressure in gas and liquid lines. If it is necessary to remove components installed in these lines such as in the case of solenoid valves.

- o Why should you tag the circuit breaker when you are working on a circuit? _____

Read the following paragraph and answer the questions.

Now you can loosen the conductor terminal connections and move the conductors out of the way. Loosen the devices used to mount the unit, these could be bolts, screws or nuts. If the unit is attached by soldering, care must be taken in heating the solder joints to prevent damage to the joints or insulation. If alignment is a factor, check distances and measurements involved. Remove the component. Set the replacement component in place, align the component if necessary and make the necessary adjustments. Make the necessary mechanical connections. Refer to your sketch and make the electrical connections. Go to the circuit breaker panel, remove the tags, and reset the breakers. Perform an operational check on the system to make sure it is operating properly.

- o Why should care be taken in heating a soldered joint? _____
- o Perform an _____ on the system to make sure it operates properly.

J3ABR54530 001-I-2 thru 4, 6, 7

Technical Training

Refrigeration and Cryogenics Specialists

ELECTRICAL

October 1982



3700 TECHNICAL TRAINING WING
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

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CIVIL ENGINEERING ORGANIZATION AND SAFETY

PART 1

DAY 1

OBJECTIVE: Using the material provided, identify the career ladder progression, three duties of the apprentice refrigeration/cryogenics specialist, mission, and organization of CE units, with no more than four errors.

PROCEDURE

Using your Study Guide/Workbook, Programmed Text 2TPT-9039-01, and classroom notes, complete the following exercises as indicated. You have approximately 15 minutes to complete this activity.

1. Enter the appropriate AFSC(s) in the space provided to show career progression.

- | | | |
|----------|-------|-------|
| a. 54550 | _____ | AB |
| | _____ | AMN |
| b. 54510 | _____ | A1C |
| | _____ | SrA |
| c. 54530 | _____ | SGT |
| | _____ | SSGT |
| d. 99000 | _____ | TSGT |
| | _____ | MSGT |
| e. 54570 | _____ | SMSGT |
| f. 54599 | _____ | CMSGT |

2. Select from the following list of duties, three that are performed by the apprentice refrigeration/cryogenics specialist. Place the letter denoting this duty in the space provided.

- a. Operate and maintain refrigeration, air conditioning, ventilation systems.
- b. Maintain tools and equipment.
- c. Supervise on-the-job training.
- d. Analyze unsatisfactory reports and correct defective equipment.
- e. Install refrigeration, air conditioning, and ventilation equipment.

1. _____
2. _____
3. _____

3. Complete the following statement of the CE mission by filling in the blanks with the correct word.

The primary mission of Civil Engineering activities is to _____,
_____, and _____ and real property facilities, and provide
related _____, _____ and other support work and services.

4. Complete the following statement related to the Civil Engineering organizational structure by filling in the blanks with the correct words.

There are seven branches responsible to the Operations Division. You will be
assigned to the _____ Branch.

PART 2

OBJECTIVE

Using material provided, identify basic facts relating to the AF Occupational Safety and Health (AFOSH) program with 80% accuracy.

PROCEDURE

Match the statements in the right column to their corresponding AFOSH program in the left column. Some items in the left column may be used more than once. Some statements in the right column may not be used (may be left blank because there is no matching item available in left column). You may use Study Guide/Workbook and class notes. You will be allowed approximately 30 minutes to complete this criterion. You must correctly answer 12 of the items to pass the criterion.

- | | |
|---------------------------------------|---|
| a. AFOSH Standards | 1. _____ Class A, Class B, Class C, and Class D |
| b. Hazards of AFSC | 2. _____ Infiltration |
| c. Job Safety | 3. _____ Reported to all levels of Command |
| d. Fire Prevention | 4. _____ Horseplay |
| e. Occupational Health Training | 5. _____ A Security Interest created in immovable property |
| f. Hazard Reporting and Abatement | 6. _____ A special AF publication which prescribes conditions necessary to provide a safe working environment |
| g. Mishap Reporting and Investigation | 7. _____ A piece of work done as part of the routine of one's occupation |
| | 8. _____ Electric feedback |
| | 9. _____ High accident potential |
| | 10. _____ Well lighted work areas |
| | 11. _____ Given to newly assigned workers |
| | 12. _____ Elimination of a safety deficiency |
| | 13. _____ Phosgene gas |
| | 14. _____ Volume I and Volume II |
| | 15. _____ Safety staff plays a key role |

PART 3

OBJECTIVE

Using material provided, state three of the rules concerning individual responsibilities to the AFOSH program. No errors allowed.

PROCEDURE

Using your classroom notes and/or Study Guide/Workbook, list three of the individual's responsibilities to the AFOSH program. You will be allowed approximately three minutes to complete this criterion.

PART 4

DAY 2

OBJECTIVE

Given the information, list the first aid procedures for electrical shock, controlling bleedings, traumatic shock, and heat exhaustion and heat stroke, with 80% accuracy.

PROCEDURE

List the first aid procedures applicable to the situations below. You must answer 8 of the 10 items correctly to pass. You will be allowed approximately 15 minutes to complete this criterion.

1. You come upon a person who has received an electric shock and is not breathing. He is no longer in contact with the live circuit. What should you do?

2. In the above situation, where would you check for a pulse?

3. When performing artificial respiration, how is an open airway to the victim's lungs assured?

4. Airman Garcia has received a wound to his right arm and he is losing blood. List the first aid steps you should take.

5. Define (traumatic) shock.

6. List the symptoms of (traumatic) shock.

7. Airman Garcia has lost enough blood that he has gone into shock. List the steps you should take to treat him for shock.

8. You are working with Airman Oliver outdoors on a hot day. She first complains of a headache. A while later she says she feels sick, dizzy, and that she might faint. You notice that she is perspiring freely. Using these symptoms, what would you expect the trouble to be?

9. List the first aid procedures you would use to help Airman Oliver.

10. *Extended exposure to a warm, humid environment
*Flushed, hot dry skin
*High body temperature
*Rapid and bounding pulse
*Semi-conscious

The conditions listed above would be symptomatic of what problem? _____

List the first aid procedures you should apply for this problem. _____

HAND TOOLS

PART 1

OBJECTIVE

Given information and randomly selected hand tools, identify them, state their use, safety precautions, and maintenance procedures with 75% accuracy.

PROCEDURES

Using the tools displayed on the table (numbered 1 through 25), identify the tools and state their use in the columns to the right of the matching numbers below. Also answer the questions on page 3-2. You are allowed to miss no more than six of the tool identifications. Questions should be at least 75% correct/complete. You have approximately 20 minutes to complete this criterion.

TOOL NO.	NAME	USE
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		

TOOL NO.	NAME	USE
23		
24		
25		

1. What is the purpose of the 15° angle on the box end wrench?

2. State the safety precautions to be observed when working with hand tools.

3. State the maintenance requirements for hand tools.

PART 2

Drill Press

OBJECTIVE

With the help of the instructor in familiarization and use of the drill press and equipment furnished, select a drill bit and drill a hole in a piece of metal. Lubricate the equipment as necessary and observe safety precautions. The hole must be within 1/8" of the point designated by the instructor.

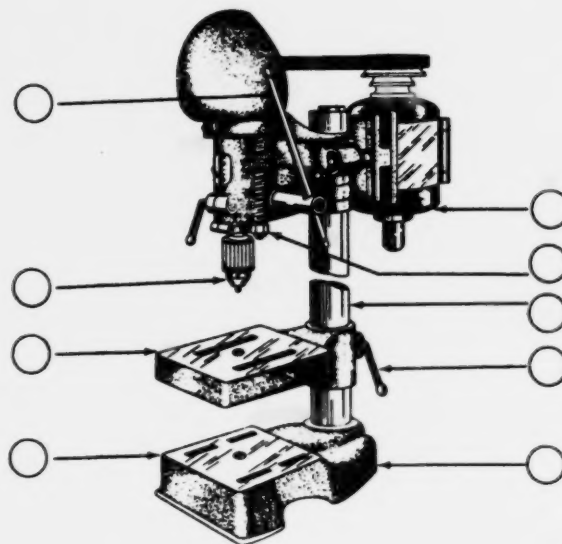
PROCEDURES

After completion of "A" below (Familiarization of the Drill Press), use the equipment assembled for you (drill press, drill bits, metal plate, center punch, ball peen hammer) and drill a hole in a piece of metal according to the steps outlined in "B" on page 3-4. You must drill the hole within 1/8" of the indicated mark. You will be allowed approximately 10 minutes to complete this objective.

A. Familiarization of a Drill Press

1. Identify the major parts of the drill stand assembly by writing in each circle the letter opposite the name of the unit.

A - LOWER TABLE
B - TABLE
C - CHUCK
D - FEED LEVER
E - MOTOR
F - BASE
G - TABLE CLAMP
H - COLUMN
I - DEPTH STOP



Drill Stand Assembly

2. What is the purpose of the key-type geared chuck?

3. Why should the pressure be eased just before drilling through a piece of metal?

4. List two safety precautions to follow when using the drill stand.

a. -----
b. -----

B. Using a Drill Press

1. Install a bit in the chuck; tighten the bit using the chuck key.
2. Mark an "X" on the metal to be drilled where the instructor wants the hole.
3. Using a center punch and hammer, tap the center punch in the center of the "X".
4. Secure the metal to the table of the drill stand with the clamps provided. (Be sure metal is aligned so the drill bit touches the center of the "X".)

CAUTION: At this point you will put on safety goggles, as flying chips can injure your eyes.

5. Turn on motor.
6. Using the feed lever, bring down the drill bit to the metal. Apply a firm steady pressure until the bit goes through.

NOTE: Always keep the drill bit cutting to prevent overheating of the drill bit. Also, too much pressure on the feed lever will overheat the bit. (Lubricate the equipment as necessary.)

CAUTION: Just before completing the hole, ease off the feed lever and then reapply pressure to complete the hole. (This prevents breakage of the bit.)

7. Let up on the feed lever slowly and turn off motor.
8. Remove the clamps and metal (being very careful as the newly drilled hole may be hot).
9. Have the instructor inspect your work.

DAY 3

ELECTRICAL PRINCIPLES AND CIRCUITS

PART 1

OBJECTIVE

Given a series of incomplete statements pertaining to elemental electricity, current, resistance, voltage, and magnetism, explain the basic principle of each by completing the statements with 80% accuracy.

PROCEDURE

Complete the following statements pertaining to electricity, current, resistance, voltage, and magnetism. You are allowed to miss a maximum of 3 of the 13 statements and will be allowed approximately 10 minutes to complete the criterion.

1. Direct current is the continuous flow of electrons in the _____ direction.
2. Alternating current is the flow of electrons in first _____ direction then in _____.
3. A volt is the _____ of electrical pressure.
4. The ampere is a measure of the _____ of _____ current electricity.
5. The resistance in a conductor depends upon what four things?

6. Extremely poor conductors are called _____.
7. An _____ is the smallest particle of element that can exist alone or in combination.
8. A molecule is the smallest portion of a _____ that retains chemical identity with the substance in mass.
9. One coulomb equals _____ X _____ or _____ electrons.
10. The lines of force of magnetism are called _____.
11. Anything that occupies space and has weight is called _____.

12. Anything that consists of atoms of only one kind and that singly or in combination constitutes all matter is called _____.

13. What is an electron?

PART 2

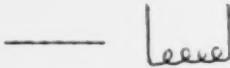
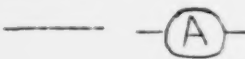
OBJECTIVE

Given ten military standard symbols to include switches, circuit breakers, and fuses, identify each and state the type and purpose of 8 of the 10 symbols.

PROCEDURE

You will be assigned one of three groups of 10 symbols below and will be required to identify 8 of the 10 symbols and give their type and purpose. Identify the symbols by placing a number from Column A in the blank to the left of the symbol in Column B. Give purpose and/or type in blank to right of symbol in Column B. You are allowed approximately 15 minutes to complete this activity.

GROUP I

<u>Column A</u>		<u>Column B</u>
1. Wires Joined		_____
2. Ammeter		_____
3. Solenoid		_____
4. DPST Switch		_____
5. Battery		_____
6. Toggle Circuit Breaker		_____
7. Fuse		_____
8. Thermocouple		_____
9. SPDT Switch		_____
10. Alternator (AC Power Source)		_____
11. Coil		_____
12. Variable Resistor		_____
		_____
		_____

GROUP II

Column A	Column B
1. SPST Switch	
2. Solenoid	
3. Ohmmeter	
4. Push Button Circuit Breaker	
5. Fixed Resistor	
6. Fuse	
7. Push/Pull Circuit Breaker	
8. SPDT Switch	
9. Crossed Wires, Not Joined	
10. Normally Closed Contacts	
11. Capacitor	
12. Transformer	
	
	

GROUP III

Column A

Column B

1. Voltmeter
2. Motor
3. Relay
4. DPST Switch
5. Light
6. Automatic Circuit Breaker
7. SPST Switch
8. Ground Wire
9. Normally Open Contacts
10. Solenoid
11. D.C. Generator
12. Fuse

_____		_____
_____		_____
_____		_____
_____		_____
_____		_____
_____		_____
_____		_____
_____		_____
_____		_____
_____		_____
_____		_____
_____		_____
_____		_____
_____		_____
_____		_____

OBJECTIVE

Given the material and information, draw a simple, series, and parallel circuit. State the current, voltage, and resistance relationship in each circuit with a total of no more than two errors.

PROCEDURE

Connect the following symbols to construct the type circuit indicated and state the current, voltage, and resistance relationship (characteristics) of each circuit. You are allowed a total of two errors and will be given approximately 20 minutes to complete the objective.

a. Simple



Voltage _____

Current _____

Resistance _____

b. Series



Voltage _____

Current _____

Resistance _____

c. Parallel



Voltage _____

Current _____

Resistance _____

d. Simple

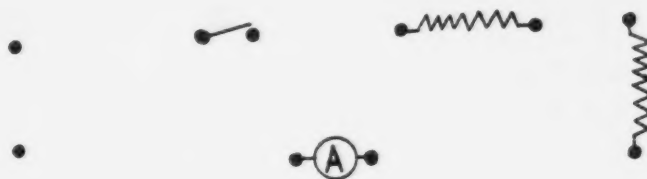


Voltage _____

Current _____

Resistance _____

e. Series



Voltage _____

Current _____

Resistance _____

f. Parallel



Voltage _____

Current _____

Resistance _____

PART 4

Wiring a Series Circuit and a Parallel Circuit

OBJECTIVE

Using an electrical trainer, construct an operative series and parallel circuit with instructor assistance.

PROCEDURE (SERIES CIRCUITS)

To gain practical experience in wiring series circuits using electrical diagrams, take the following PRECAUTIONS:

Remove jewelry

Turn electrical power OFF before wiring circuits or removing units

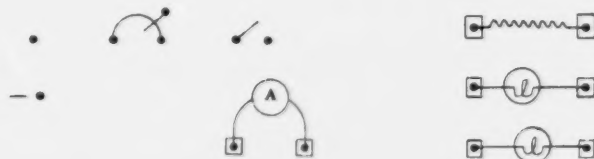
Be sure of correct multimeter setting before making measurements

and proceed with the following numbered steps:

1. In the space below the units to be included in the series circuit are a circuit breaker, a SPST switch, an ammeter, and two lamps. Draw lines on the following diagram to represent the wires you will place on the trainer.



2. Have the instructor check your diagram.
3. Wire the circuit on the trainer using your diagram as a guide.
4. Have the instructor check your circuit.
5. In the diagram below, use lines to represent how the fixed resistor would be wired in series to your circuit.



6. Have the instructor check your diagram.
7. Remove the wires you placed on the trainer.

8. Complete the following statements.

- a. A series circuit is a circuit with _____ path for current flow.
- b. The sum of the voltage drops should equal the _____ voltage.
- c. Current is the _____ throughout a series circuit.
- d. Total resistance may be found in a series circuit by _____
_____ the resistance of all units.
- e. As units of resistance are added in a series circuit, will the current flow decrease, increase, or remain the same?

- f. As units of resistance are added in a series circuit, will the total resistance decrease, increase, or remain the same?

PROCEDURE (PARALLEL CIRCUITS)

To gain practical experience in wiring parallel circuits using electrical diagrams, take the following PRECAUTIONS

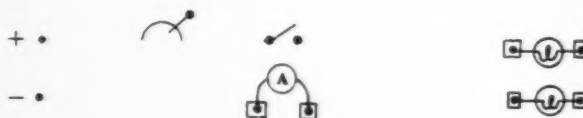
Remove jewelry

Turn electrical power OFF before wiring circuits or removing units

Be sure of correct multimeter setting before making measurements

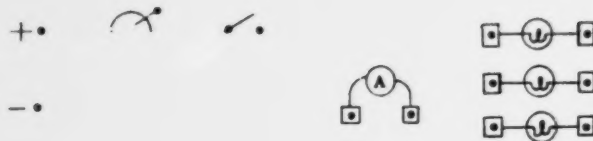
and proceed with the following numbered steps:

1. In the space below, the units to be included in the circuit are a circuit breaker, a SPT switch, an ammeter to indicate total current flow, and two lamps in parallel. Use lines to represent the wires you will place on the trainer.



2. Have the instructor check your diagram.
3. Wire the circuit on the trainer using your diagram as a guide.
4. Have the instructor check your circuit.

5. In the diagram below, use lines to represent how a third light would be wired in parallel to your circuit.



6. Have the instructor check your diagram.

7. Remove the wires you placed on the trainer.

8. Complete the following statements:

- a. A parallel circuit is one with _____ or more paths for current flow.
- b. The voltage drop of a unit in a parallel circuit should be equal to the _____ voltage.
- c. Total current is the _____ of the currents from each path in a parallel circuit.
- d. When additional units are added in parallel in a circuit, will the total resistance increase, decrease, or remain the same?

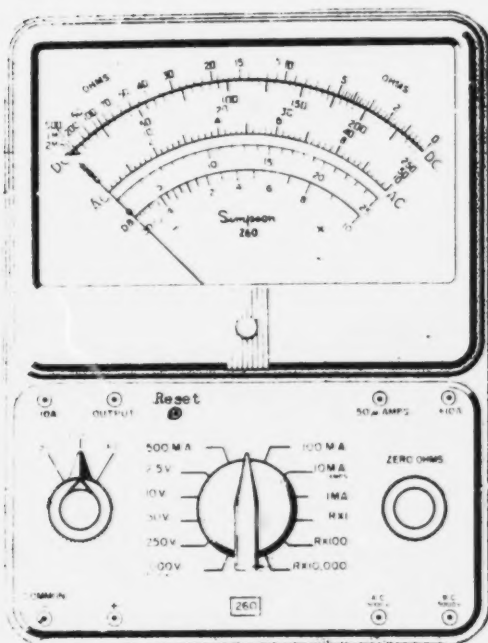
- e. When units are added in parallel in a circuit, will the total current increase, decrease, or remain the same?

OBJECTIVE

Using a volt ohmmeter, select the proper mode and determine the electrical values of a designated electrical circuit $\pm 5\%$ of meter scale value with no more than one assist on safety.

PROCEDURE

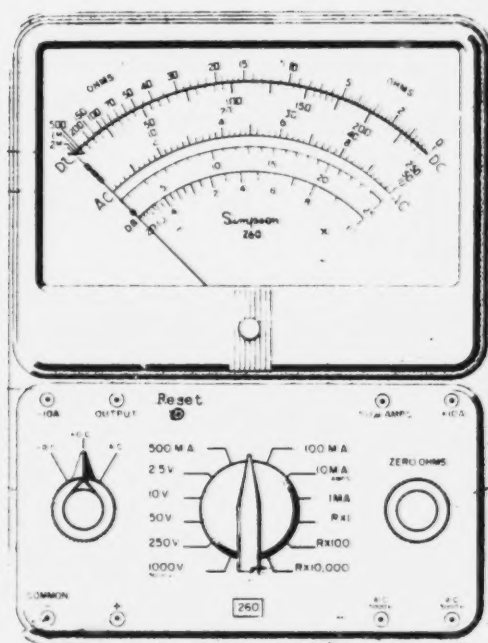
Draw on the following meter faces the indicating needle in its proper position. Then fill in the blanks below the meter faces to show the proper setting of the ac/dc knob and range switch knob for the meter indication given. You are allowed approximately 20 minutes to complete the objective.



Indicating 24 V DC

Range Switch Knob _____

AC/DC Knob _____

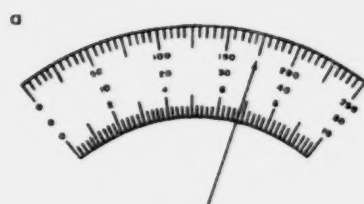


Indicating 1.5 V DC

Range Switch Knob _____

AC/DC Knob _____

In the diagram below, different range switch knob positions are listed below each meter face. Write what the meter would be indicating on each specific range in the blanks provided for DC voltages.

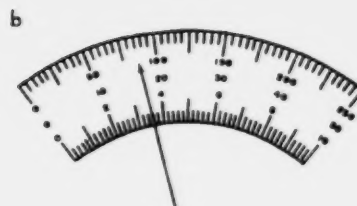


Range Switch Knob

1000 V _____

50 V _____

10 V _____



Range Switch Knob

250 V _____

50 V _____

10 V _____



Range Switch Knob

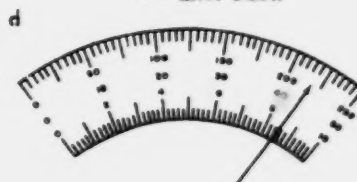
250 V _____

2.5 V _____

1000 V _____

10 V _____

50 V _____



Range Switch Knob

250 V _____

50 V _____

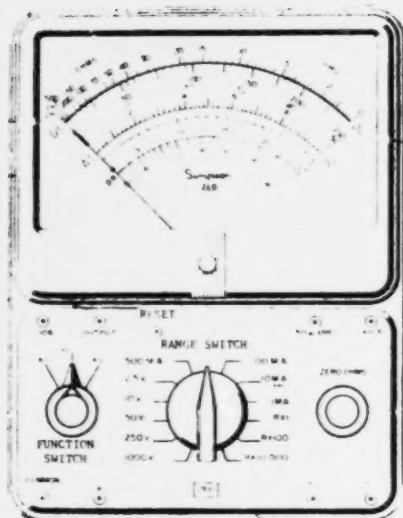
1000 V _____

10 V _____

2.5 V _____

Using the Multimeter as an AC Voltmeter

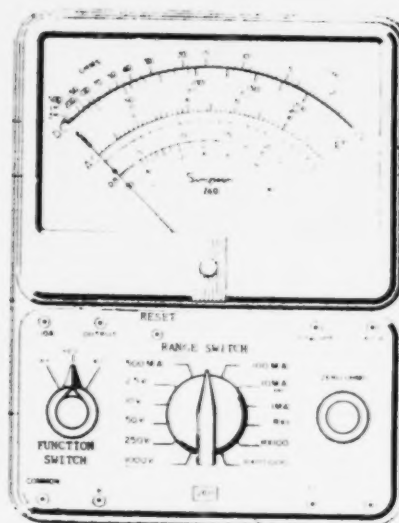
Draw on the following meter faces the indicating needle in its proper position. Then fill in the blanks below the meter faces to show the proper setting of the range switch knob and the ac/dc knob for the meter indication given.



Indicating 110 V AC

Range Switch Knob _____

AC/DC Knob _____



Indicating 220 V AC

Range Switch Knob _____

AC/DC Knob _____

In the diagram below, different range switch knob positions are listed for each meter face. Write what the meter would be indicating on each specific range in the blanks provided.



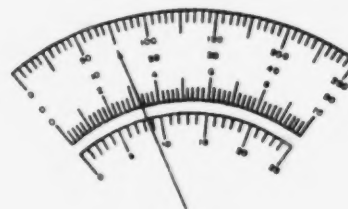
Range Switch Knob

250 V _____

50 V _____

10 V _____

1000 V _____



Range Switch Knob

2.5 V _____

50 V _____

250 V _____

1000 V _____

Set the trainer switch to AC position.

NOTE: Red light should burn.

Set the multimeter to measure AC voltages.

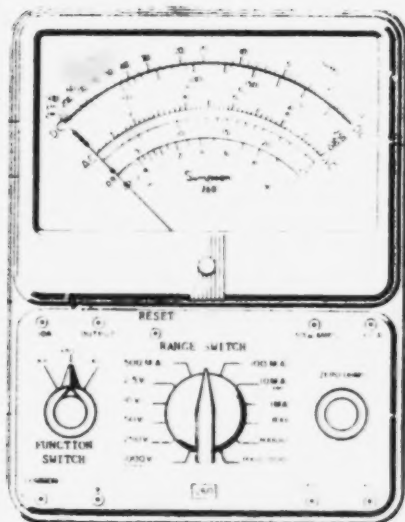
Make the AC voltage measurements between trainer terminals indicated below.

Trainer Terminals

Voltage

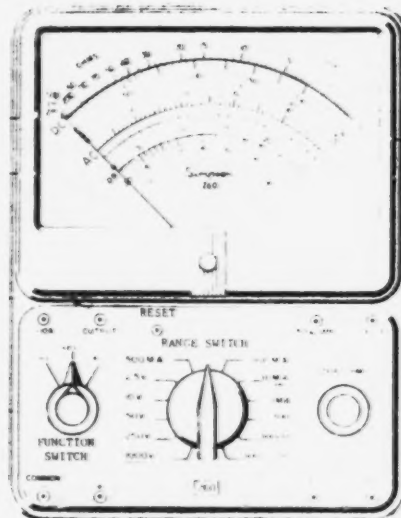
- 2 to 17
- 4 to 17
- 1 to 2
- 3 to 6
- 5 to 10
- 6 to 12
- 7 to 14
- 10 to 13
- 12 to 17
- 14 to 16
- 14 to 18
- 15 to 17
- 16 to 17
- 17 to 18

Draw on the following meter faces the indicating needle in its proper position. Then fill in the blanks below the meter faces to show the proper setting of the range switch knob for the meter indication given.



Indicating 5 Ohms

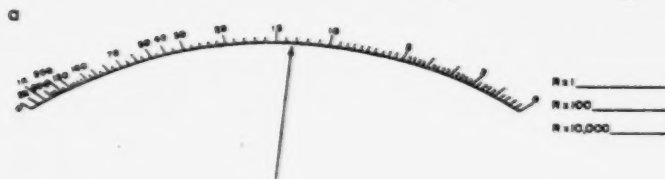
Range Switch Knob -----



Indicating 2000 Ohms

Range Switch Knob -----

In the diagrams below different range switch know positions are listed for each meter face. Write in the blanks provided what the meter would be indicating for each specific range.



Set the trainer switch to the OHMS position.

Set the multimeter to measure resistance.

Make and record resistance measurements between trainer terminals indicated below:

Trainer Terminals

Ohms

1 to 3
1 to 5
1 to 11
2 to 10
2 to 12
3 to 13
4 to 10
5 to 11
5 to 13
7 to 9
8 to 16
9 to 17
10 to 12
11 to 13
16 to 18

Unplug the trainer.

DAY 6

WIRING SYSTEMS, MOTORS, MOTOR STARTERS, AND OVERLOADS

PART 1

OBJECTIVE

Given the information, state the purpose and function of two, three, and four wire electrical systems with no more than three errors.

PROCEDURE

In the spaces provided, state the purpose and function of two, three and four wire systems. You will be allowed approximately 10 minutes to complete this criterion and will be allowed no more than 3 errors.

1. Two wire systems:

- a. Purpose: _____

- b. Function: _____

2. Three wire systems:

- a. Purpose: _____

- b. Function: _____

3. Four wire systems:

- a. Purpose: _____

- b. Function: _____

PART 2

OBJECTION

Given the information, state the general construction features of single and three-phase motors with no more than two errors.

PROCEDURE:

Using the diagrams, correctly identify the major components of a single and three-phase motor as indicated. You will be allowed approximately 10 to 15 minutes to complete this criterion and are allowed three errors total.

1. The illustration below shows the major parts of a single-phase motor. In the blank space provided, write the name of the appropriate component.

A. _____

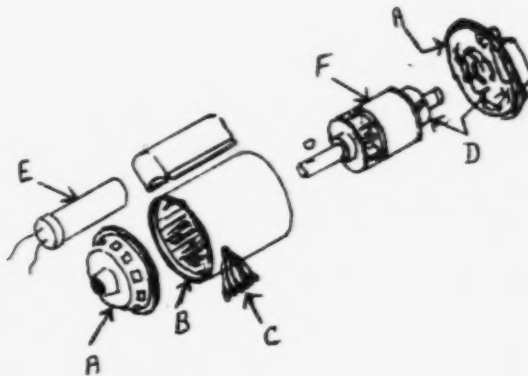
D. _____

B. _____

E. _____

C. _____

F. _____



Major Parts of a Single-Phase Motor

Three-Phase Motor Construction

2. Identify these parts by writing the name of each part in the space provided.

A. _____

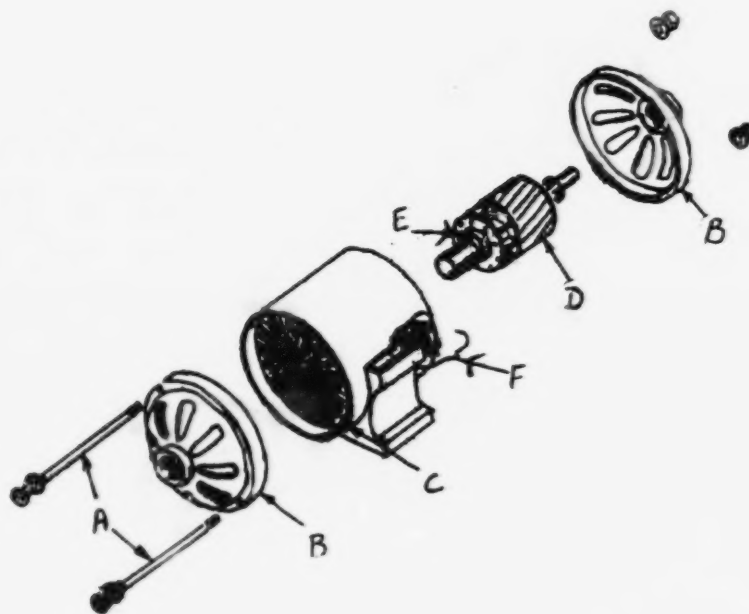
D. _____

B. _____

E. _____

C. _____

F. _____



Major Parts of a Three-Phase Motor

3. State the general construction features of a single-phase motor.

4. State the construction features of a three-phase motor.

OBJECTIVE

Given the information, list the steps for installing and servicing electric motors with no more than two errors.

PROCEDURE

Using the information below, list, in logical sequence, the steps for installing and servicing electric motors. You will be allowed approximately 10 minutes to complete this criterion and may make a maximum of two errors total.

1. Installation

- Step 1 _____
- Step 2 _____
- Step 3 _____
- Step 4 _____
- Step 5 _____
- Step 6 _____
- Step 7 _____
- Step 8 _____
- Step 9 _____
- Step 10 _____

Install the replacement motor.

Remove and label the wires.

Disconnect power.

Mount hold-down bolts or brackets loosely.

Remove hold-down bolts or brackets.

Remove the bad motor.

Align the replacement motor.

Reconnect the wires.

Turn power on and determine for proper operation.

Secure the replacement motor.

2. Servicing

- Step 1 _____
- Step 2 _____
- Step 3 _____
- Step 4 _____
- Step 5 _____
- Step 6 _____

Visually inspect the motor for defects.

Service motor as required.

Clean the motor.

Disconnect the power.

Operate the motor and observe the operation.

Remove guards.

PART 4

OBJECTIVE

Given the information and using a motor trainer and a multimeter, determine the start and run windings of an electric motor, connect the motor and reverse its rotation with instructor assistance.

PROCEDURES

A. Determine start and run windings by following the steps below. You will be allowed approximately 20 minutes to complete this criterion.

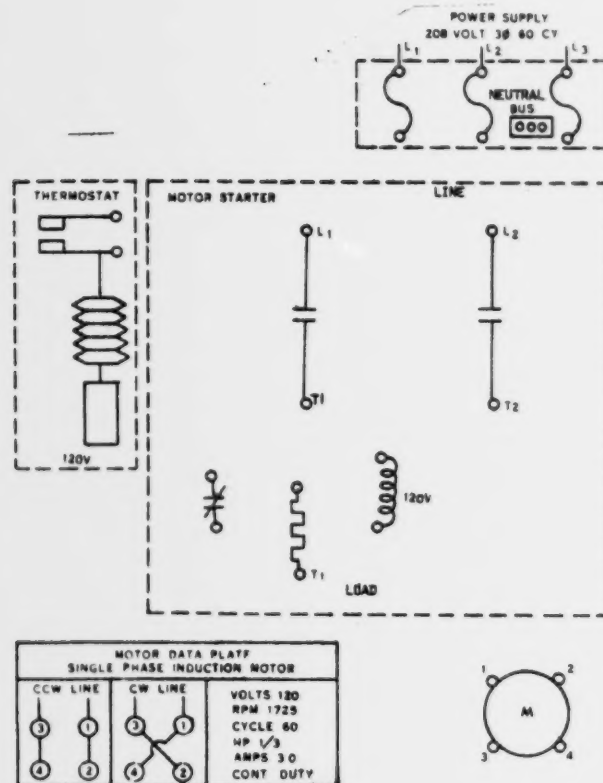
1. Obtain a multimeter from the tool cabinet.
2. Select an electric motor as directed by the instructor.
3. Set up and check the multimeter to read resistance.
4. Draw a picture of the terminal arrangement.
5. Number the terminals in your drawing 1, 2, and 3.
6. Use the multimeter and take reading across each set of terminals. Record the reading in the spaces provided below:
 - a. 1 and 2 = _____
 - b. 1 and 3 = _____
 - c. 2 and 3 = _____
7. The highest reading is the _____ and _____ terminals.
8. The lowest readings are the _____ and _____ terminals.
9. The middle reading is the _____ and _____ terminals.
10. Why must the middle and lowest readings equal the highest reading?

11. Label the terminals in your drawing R, S, and C, representing run, start, and common.

B. Wiring 1Ø Induction Motors

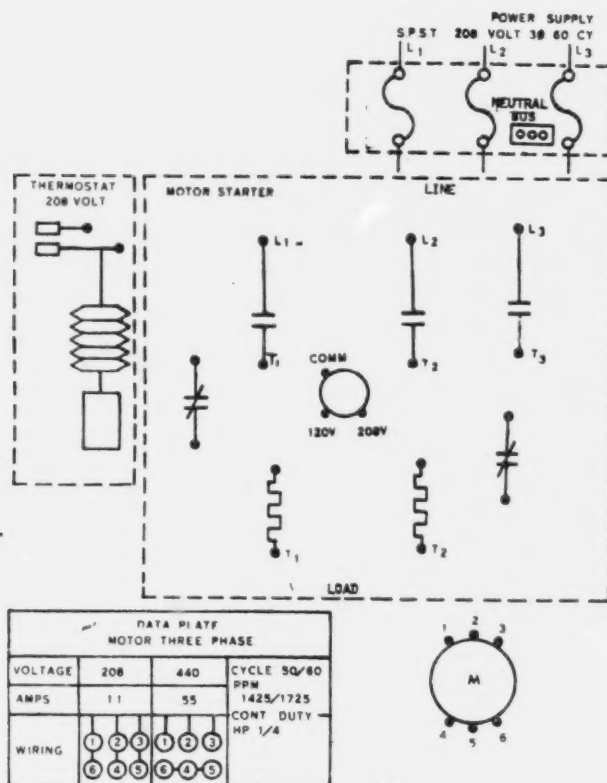
1. Using the data plate information and symbols available in figure below, connect the motor to the power supply using the across-the-line motor starter.
2. Connect the motor to rotate clockwise.

3. How many hot leads are needed to operate the motor? _____
4. Procedures for reversing the rotation of the single phase motor:
- Disconnect power.
 - Reverse the START winding leads or the RUN winding leads.
 - Connect power.
 - Check rotation.



C. Wiring 3Ø Induction Motors

1. Using the information and symbols available in figure below, connect the motor to the power supply using the across-the-line motor starter.
2. How many hot leads are needed to operate the motor?
3. The direction of rotation can be changed by changing what terminal leads?



D. Reversing rotation (3ø)

CAUTION: Remove jewelry

1. Connect trainer to power and turn on to observe direction of rotation.
2. Turn motor off.
3. DISCONNECT TRAINER FROM POWER
4. Reverse any two of the leads connecting to the motor (T_1 , T_2 , T_3) at the motor starter or at the motor.
5. Turn power back on and operate to observe that the rotation has been reversed.
6. Turn off power, unplug, return equipment to prior position/storage.

DAY 8

PART 5

OBJECTIVE

Using an electrical trainer, service the motor starters with instructor assistance.

PROCEDURE:

Service the motor starters using the steps below. Record your findings in the space provided.

CAUTION: Disconnect the trainer from the power source and remove jewelry.

1. Check for the presence of dust, grease, oil and dirt.
2. Check for overheating of the electrical components.
3. Check electrical wires for fraying and broken strands.
4. Check electrical connections for tightness.
5. Check for short circuits and grounds in the electrical wiring.
6. Inspect the contacts for pitting and proper alignment.
7. Inspect the springs to ensure proper tension.
8. Have the instructor check your work.

PART 6

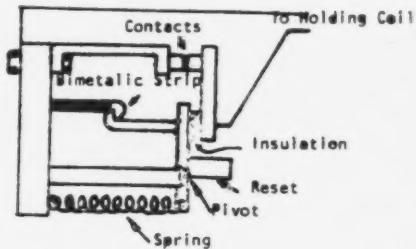
OBJECTIVE

Given the information, state the types and function of electrical overload protectors with no more than two errors.

PROCEDURE

In the spaces provided, state the types and functions of the electrical overload protectors. You are allowed two errors total and will be allowed approximately 10 minutes to complete this criterion.

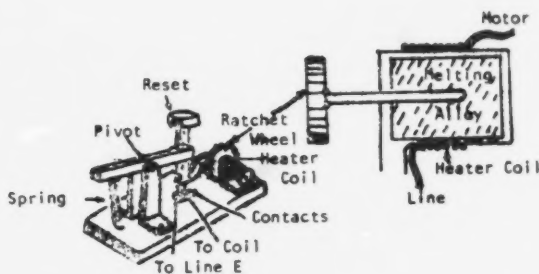
1.



A. Type: _____

B. Function: _____

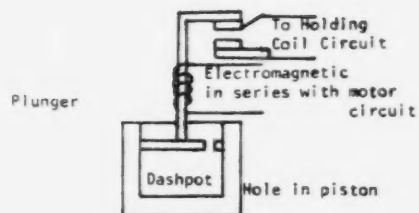
2.



A. Type: _____

B. Function: _____

3.



A. Type: _____

B. Function: _____

SCHEMATIC INTERPRETATION AND ELECTRICAL TROUBLESHOOTING

PART 1

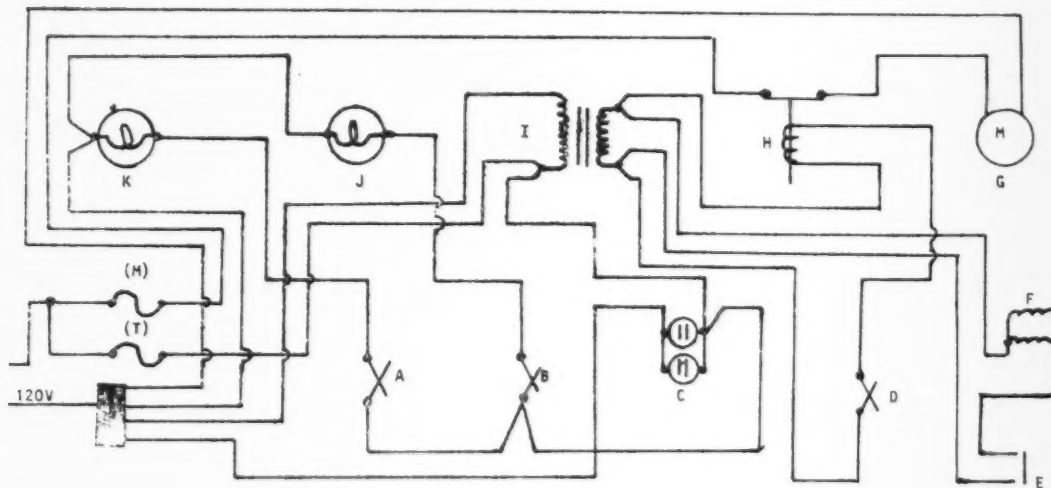
OBJECTIVE

Given a schematic diagram, trace the circuit designated by the instructor, with no more than two errors.

PROCEDURE

Using the figure below and/or the trainer designated by your instructor, trace out the circuits and complete the following statements. Two errors are allowed. You have approximately 30 minutes to complete this criterion.

1. Fuse _____ supplies power to transformer I.
2. The voltage across the primary coil of transformer I is _____ volts.
3. Buzzer F and Relay H are wired in (series, parallel).
4. Switch D controls _____.
5. Fuse _____ supplies power to lights J and K.
6. Switch A controls light _____.
7. Lights J and K are wired in (series, parallel).
8. Motor G is controlled by _____.

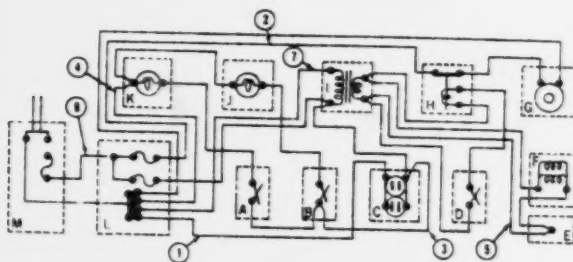


Troubleshooting Single-Phase 120-Volt Circuit

Analyzing Electrical Circuits Using a Diagram

In order to prepare to troubleshoot a 120-Volt Circuit, you will first analyze the diagram below, working independently. STUDY THE DIAGRAM CAREFULLY.

The wires on the diagram in the figure have been numbered 1 through 7. By each numbered wire below, list the unit(s) by letter that would be inoperative if that specific wire were open. DO NOT LIST SWITCHES SINCE THEY ARE NOT UNITS OF RESISTANCE. When you have completed your list, have the instructor check your work.



120-Volt Single Phase

WIRE NUMBER	UNIT(S) INOPERATIVE	WIRE NUMBER	UNIT(S) INOPERATIVE
1		5	
2		6	
3		7	
4			

Troubleshooting
Determining Location of Troubles by Use of Meters

PART 2a*

OBJECTIVE

Working as a team and using an electrical trainer and a meter, safely locate five of six instructor induced malfunctions. (*This objective may be completed on this 120V trainer or on the 3Ø trainer.)

PROCEDURES

Obtain a meter and trainer assignment. You will work with a classmate. Take one copy of this workbook to the trainer area with you. Use only the TOP half, 120-volt part, of the trainer. You have approximately three hours to complete this activity. Proceed in the following manner:

1. Note that the diagram you have been studying is also the diagram of the trainer assigned to you by the instructor (see top, left of your trainer).
2. Be sure that all control devices are in the OFF position.
3. Be sure that the trouble switches at the right end of the trainer are in the normal position.
4. Connect the trainer to the wall receptacle.
5. Turn the switchbox at the end of the trainer ON.
6. Turn the 120-volt switchbox ON.
7. Make an operational check of all the units.
8. Obtain a multimeter to be used in locating the trouble.
9. Start your troubleshooting by turning trouble switch No. 1 (on the right end of the trainer) to the trouble position.
10. Operate all circuits to determine the defective circuit.
 - a. What is the type of trouble? Record your answer in the proper column in the chart below, to the right of Number 1.
 - b. Where is it located? Record your answer in the proper "location" column in the chart below.
 - c. What meter did you use to find its location? Record your answer in the proper "meter used" column below.
11. Turn No. 1 to normal position. Turn No. 2 to the trouble position. Operate all units. Proceed with your troubleshooting. Fill in the blanks below.

TROUBLE SWITCH	TYPE OF TROUBLE	LOCATION	METER USED
1			
2			
3			
4			
5			
6			

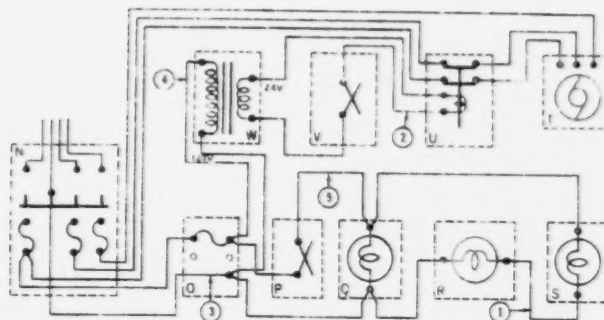
12. Turn all trouble switches to the normal position. Have your instructor check your work.
13. When the instructor has determined that you have a passing score on the objective (5 out of 6), turn the master switch off and disconnect the trainer from the wall receptacle.

Troubleshooting Three-Phase Circuits

Analyzing Electrical Circuits Using a Diagram

In order to prepare to troubleshoot a three-phase circuit, you will first analyze the diagram below, working independently. STUDY THE DIAGRAM CAREFULLY.

The wires on the diagram in the figure have been numbered 1 through 5. By each numbered wire below, list the unit(s) by letter that would be inoperative if that specific wire were open. DO NOT LIST SWITCHES SINCE THEY ARE NOT UNITS OF RESISTANCE. When you have completed your list, have the instructor check your work.



WIRE NUMBER	UNIT(s) INOPERATIVE	WIRE NUMBER	UNIT(s) INOPERATIVE
1		5	
2			
3			
4			

Troubleshooting Determining Location of Troubles by Use of Meters

PART 2b*

OBJECTIVE

Working as a team and using an electrical trainer and a meter, safety locate five of six instructor induced malfunctions. (*This objective may be completed on this three-phase trainer or on the 120V trainer.)

PROCEDURES

Obtain a meter and trainer assignment. You will work with a classmate. Take one copy of this workbook to the trainer area with you. Use only the BOTTOM half, three-phase part, of the trainer. You are allowed approximately 3 hours to complete this activity. Proceed in the following manner.

1. Note that the trainer assigned to you is the same as the diagram you have been analyzing INDEPENDENTLY, the three-phase. This diagram is also on your trainer (top, right) for your use.
2. Be sure all control devices are in the OFF position.
3. Be sure all trouble switches at the right end of the trainer are in the normal position.
4. Connect the trainer to the wall receptacle.
5. Turn the switch box at the end of the trainer ON.
6. Turn the 208-volt switchbox ON. (Only the bottom half of the trainer 208--volt part is to be used.)
7. Make an operational check of all the units. If there is a malfunction in the trainer, report it to the instructor.
8. Start your troubleshooting by turning trouble switch No. 7 (on the right end of the trainer) to the normal position. Operate all circuits to determine the defective circuit.
 - a. What is the type of trouble? Record your answer in the proper column in the chart below, to the right of Number 7.
 - b. Where is it located? Record your answer in the proper "location" column in the chart below.
 - c. What meter did you use to find its location? Record your answer in the proper "meter used" column below.
9. Turn switch No. 7 to the normal position. Turn No. 8 to the trouble position. Operate all circuits. Proceed with your troubleshooting. Fill in the blanks below.

TRouble SWITCH	TYPE OF TROUBLE	LOCATION	METER USED
7			
8			
9			
10			
11			
12			

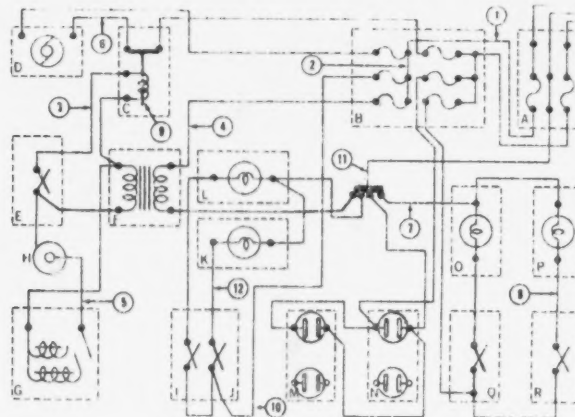
10. Turn all trouble switches to the normal position. Have your instructor check your work.
11. When the instructor has determined that you have a passing score on the objective (5 and 6), turn the master switch off and disconnect the trainer from the wall and receptacle.

Troubleshooting 220-Volt Single-Phase Circuits

Analyzing Electrical Circuits Using Diagram

In order to prepare to troubleshoot a 220-Volt Single-Phase circuit and to use electrical test equipment for isolating troubles, you will first analyze the diagram below, working INDEPENDENTLY. STUDY THE DIAGRAM CAREFULLY.

The wires on the diagram have been numbered 1 through 12. By each numbered wire below, list the unit(s) by letter that would be inoperative if that specific wire were open. DO NOT LIST SWITCHES SINCE THEY ARE NOT UNITS OF RESISTANCE. When you have completed your list, have the instructor check your work.



WIRE NUMBER	UNIT(s) INOPERATIVE	WIRE NUMBER	UNIT(s) INOPERATIVE
1		7	
2		8	
3		9	
4		10	
5		11	
6		12	

PART 3a*

OBJECTIVE

Working as a member of a team, using electrical test equipment and an electrical trainer, isolate three of six instructor induced malfunctions. (*This objective may be completed using the following assigned 6 troubles OR those assigned for PART 3b.)

PROCEDURES

Obtain a meter and assignment of teammate and trainer from your instructor. Take a copy of this workbook to the trainer with you. You are allowed approximately two hours to complete this activity. Proceed in the following manner.

1. Note that the diagram you have been studying INDEPENDENTLY is also the diagram of the trailer assigned to you by the instructor (ss at the top of the trainer). Use only this 220-Volt, Single-Phase trainer assigned to you.
2. Be sure all control devices are in the OFF position.
3. Be sure all the trouble switches at the RIGHT end of the trainer are in the normal position.
4. Connect the trainer to the wall receptacle, turn the master switch at the END of the trainer ON, then turn the 220-volt, single-phase SWITCHBOX to ON position.
5. Make an operational check of all units on the trainer (INFORM THE INSTRUCTOR of any MALFUNCTION.)
6. Start your troubleshooting by turning to the TROUBLE ON position the first trouble-switch number listed below. Proceed with locating and recording the information asked for below as you have in previous exercises. Remember to turn each trouble-switch to the normal position before turning another on.
8. When you have completed all troubles, turn switches to the normal positions and have the instructor check your work.
9. When the instructor has determined that you have a passing score on the objective (3 of 6), turn the master switch and switchbox to OFF position and disconnect the trainer from the wall receptacle.

TROUBLE SWITCH	TYPE OF TROUBLE	LOCATION	METER USED
2			
3			
4			
5			
6			
12			

PART 3b*

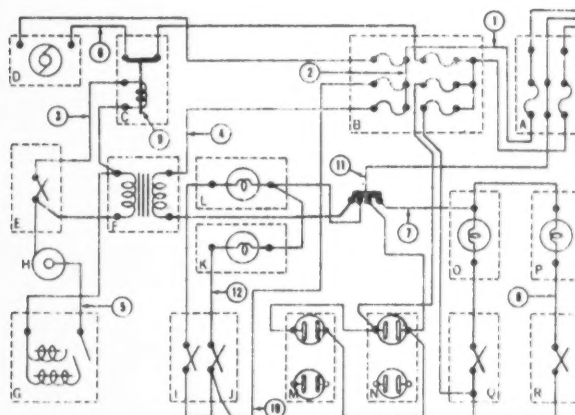
OBJECTIVE:

Working as a member of a team, using electrical test equipment and an electrical trainer, isolate three of six instructor induced malfunctions. (*This objective may be completed using the following assigned 6 troubles OR those assigned for PART 3a.)

PROCEDURES

(PART 3b procedures are identical to PART 3a. Turn to the previous page to use those then proceed to locate the troubles for the troubleswitches listed below the record the information as needed in the chart.)

TROUBLE SWITCH	TYPE OF TROUBLE	LOCATION	METER USED
6			
7			
8			
9			
10			
11			



DAY 10

PART 4

OBJECTIVE

Given the information, state the basic steps for replacing defective electrical units and components with no more than two errors.

PROCEDURE

1. State the basic steps for replacing defective electrical units and components. You will be allowed approximately 10 minutes to complete this objective.

a.

b.

c.

d.

e.

f.

OBJECTIVE

Using an electrical trainer given a minor electrical discrepancy repair the circuit or unit with no more than one instructor assist.

PROCEDURE

Note that one of the diagrams you studied previously is also the diagram of the trainer assigned you by the instructor. Using the steps below, locate and correct the electrical discrepancy in the unit assigned to you. You will be allowed approximately 60 minutes to complete this objective.

1. Be sure all control devices are in the OFF position.
2. Connect the trainer to the wall receptacle.
3. Turn the switch box at the end of the trainer ON.
4. Turn the 120-volt single-phase switch box ON.
5. Obtain a multimeter to be used in locating the troubles.
6. Operate all circuits to determine the defective circuit.
 - a. What is the type of trouble? _____
 - b. Where is it located? _____
 - c. What meter was used to find the location? _____
 - d. What was done to repair the unit? _____
7. When you have located and repaired your malfunction, have your instructor check your work.

Technical Training

Refrigeration and Cryogenics Specialist

FUNDAMENTALS

October 1982



USAF TECHNICAL TRAINING SCHOOL
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

RGL: --

DESIGNED FOR ATC COURSE USE

DO NOT USE ON THE JOB

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Assignments:

Prior to Day:

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Supersedes SGs 3ABR54530-I-1, I-3 thru I-9, June 1981.

REFRIGERATION LINES AND FITTINGS

OBJECTIVE:

This Study Guide/Workbook will acquaint you with:

- o Identification of tubing/pipe by size and type
- o Measuring, cutting and bending copper tubing
- o Identification of refrigeration fitting by size and type
- o Cutting, flaring and swaging tubing

INTRODUCTION

This Study Guide/Workbook will prepare you for the indicated days of instruction. You must complete the assignments and be prepared for evaluation at the beginning of each day. The following assignment will be referenced from various chapters in the modern refrigeration and air conditioning textbook.

DIRECTED STUDY

Assignment in Preparation for Day 11:

I. Refrigeration tubing, size and type identification

A. Read Paragraph 2-1 and answer the following questions:

1. Most tubing used in refrigeration and air conditioning is made of (circle correct answer)

a. aluminum	c. copper
b. stainless steel	d. steel
2. All tubing used in air conditioning and refrigeration work is carefully processed to be sure that it is _____.
3. Most tubing used in air conditioning and refrigeration is the _____ thickness.
4. Most air conditioning and refrigeration tubing is protected from inside contamination by two factory practices; what are they?
_____ and _____

B. Read Paragraph 2-2 and answer the following questions:

1. When soft copper tubing is annealed, that means it is (circle correct answer)

a. connected	c. sealed
b. heated	d. hardened
2. In what lengths are rolls of soft copper tubing available?

3. What happens to soft copper tubing when it is bent or hammered on?

4. Copper tubing used in refrigeration and air conditioning is measured by

- C. Read Paragraph 2-3 and discuss installation principles as applied to hard drawn copper.

- D. Read Paragraph 2-4 and explain why steel tubing ONLY should be used in R-717 (ammonia) systems.

- E. Read Paragraph 2-10 and answer the following questions:

1. What are some applications where nominal size copper tubing is used?
2. When is nominal size copper tubing used in connection with refrigerants?
3. O.D. size is _____ larger than nominal size.

II. Cutting and bending copper tubing

- A. Read Paragraph 2-11 and answer the following questions:

1. What tools are used to cut copper tubing?
2. Discuss the application of each tool listed in the answer to question #1.
3. Discuss the precautions to be observed when using the tools listed in question #2.
4. How may a full-wall thickness be obtained after cutting a piece of tubing?

B. Read Paragraph 2-12 and answer the following questions:

1. How will properly bent tubing affect its installation:

2. Be very careful when bending tubing to keep it _____.

3. Why should tubing be bent gradually? _____

4. Explain the use of a spring bender and note precautions to be taken.

5. For more accurate bending, which type bender is used? _____

C. Read Paragraph 2-18 and answer the following:

1. Code No. 3 indicates the fitting fits 3/16" tubing. What code number would fit 3/8" tubing? _____

2. Fittings are usually made of what? _____

D. Read Paragraph 2-14 to answer the following:

1. Most flares are made at a _____ degree angle.

2. What are the advantages of the double flare?

HOMEWORK for Day 11:

Read the following paragraphs from the Modern Refrigeration and Air Conditioning textbook. Be prepared to discuss material and answer questions on the assigned subject matter:

Paragraphs 2-15 thru 2-17, 2-19/20, 2-24, 2-26 and 2-27.

SOLDERING AND BRAZING

OBJECTIVE

To familiarize you with the operation of the hydrocarbon and oxyacetylene torch, the various methods used for soldering, and the different types and application of solder.

INTRODUCTION

In the air-conditioning and refrigeration career field, you as the mechanic will have many opportunities to repair leaks and fabricate tubing which will require the use of soldering and good soldering methods. In this lesson you will learn the proper way to prepare tubing, apply solder, and which solders to use for the many different jobs.

INFORMATION

The following assignments will be referenced from various chapters in the Modern Refrigeration and Air Conditioning textbook.

DIRECTED STUDY

Assignment in Preparation for Day 12:

I. Soldering copper tubing

A. Read Paragraph 2-21 and complete the following:

1. Explain the term "soldering".

2. How are the parts to be soldered prepared for assembly?

3. Explain the procedure used to insure that flux is spread evenly over the surfaces that are to be fitted together.

4. List four procedural steps for soldering.
 - a. _____
 - b. _____
 - c. _____
 - d. _____
5. What is the purpose of flux to the soldering process?

6. What important fundamental of good soldering is stated in this paragraph?

7. According to this paragraph, why should oxygen never be used for testing for leaks?

B. Read Paragraph 2-22 and answer the following:

1. What type soldering can be used for a very strong, leakproof connection?

2. List precautions to be taken when doing silver solder/brazing.

3. What is the usual free flow temperature for silver solder?

C. Read Paragraph 2-28 and complete the following:

1. What is the most desirable type of epoxy adhesive and of what does it consist?

2. What types of materials will epoxy adhere to?

3. In making an epoxy repair, how does one determine the type of repair to be made? Explain.

4. Why is it recommended that epoxy compound be purchased from a refrigeration wholesaler?

5. What precaution is given to the users of epoxy?

6. Give procedures for using epoxy compound?

a.

b.

c.

d.

HOMEWORK for Day 12:

Read the following paragraphs from the Modern Refrigeration and Air Conditioning textbook. Be prepared to discuss material and answer questions on the assigned subject matter:

Paragraphs 2-23, 14-21, 14-22, 28-52

PRINCIPLES OF PHYSICS

OBJECTIVE

To help you in learning physics as related to refrigeration, the refrigeration cycle, and refrigerants and their characteristics.

INTRODUCTION

Look at the refrigeration industry and the many improvements that have been made over the last 30 years. In the future, we will continue to use refrigeration in the preservation of food and medicine, but the greatest strides will be in the fields of comfort and equipment cooling.

INFORMATION

The following assignments will be referenced from various chapters in the Modern Refrigeration and Air Conditioning textbook.

DIRECTED STUDY

Assignment in Preparation for Day 13:

1. Principles of physics

A. Read Paragraph 1-18 and list the three states in which substances exist.

1. _____
2. _____
3. _____

B. Read Paragraph 1-19 and answer the following questions:

1. Define a solid. _____

2. Explain how the rate of vibration of molecules of a solid are affected by temperature.

3. Read Paragraph 1-20 and define a liquid. _____

4. Read Paragraph 1-21 and answer the following:

a. Define a gas. _____

b. List two things that will determine the physical state of a substance.

(1) _____

(2) _____

5. Read Paragraph 1-30 and define sensible heat. _____

6. Read Paragraph 1-31 and 1-32 and answer the following:

a. Define specific heat. _____

b. Define latent heat. _____

c. List the types of latent heat required to change the state of a substance from a solid to a liquid, and from a liquid to a solid.

(1) _____

(2) _____

d. All of the basic operations of the compression refrigeration cycle are based on two types of heat. What are they?

(1) _____

(2) _____

e. State the formula for calculating the amount of sensible heat added or taken away from a substance.

7. Read Paragraphs 1-3 and 1-4 and answer the following:

a. What is heat? _____

b. What is the U. S. Conventional unit of heat? _____

c. Explain how heat flows. _____

8. Read Paragraphs 1-45 through 1-48 and describe the methods of heat transfer.

- a. _____

- b. _____

- c. _____

9. Read Paragraph 1-29 and define the term British Thermal Unit.

10. Read Paragraph 1-15 and answer the following:

- a. Define pressure. _____

- b. At sea level, the normal pressure of the atmosphere is _____
- c. What effect does pressure have on the refrigeration system operation?

11. Read Paragraph 1-17, study figure 1-13, 1-14, and answer the following:

- a. Explain the use of the compound gauge, what does it measure?

- b. A pressure reading of 0 psi on the gauge is equal to what absolute pressure? Why?

- c. Pressures lower than atmospheric pressures are called what?

- d. What is a manometer used for? _____

12. Read Paragraphs 1-34 and 1-35 and answer the following:

- a. Explain the effect of pressure on the boiling point of a liquid.

- b. Increasing the pressure would affect the freezing temperature of water. Would it lower or raise the temperature at which the water would freeze?

HOMEWORK for Day 13:

Read the following paragraphs from the Modern Refrigeration and Air Conditioning textbook. Be prepared to discuss material and answer questions on the assigned subject matter:

Paragraphs: 1-8, 1-28, 1-42, 1-43 through 1-44, 1-58, 2-52 through 2-56, 2-69, 9-82
15-28, 28-20, 28-62, 28-63.

HOMEWORK IN PREPARATION FOR DAY 14

I. Pressure-temperature relationship, refrigerants

- A. Read Paragraph 1-42 and define "refrigerant."
- B. Read Paragraph 2-69 and list at least four facts or precautions concerning refrigerants and handling of refrigerants.
- C. Read Paragraph 9-28 and answer the following:
1. The evaporator temperature will be _____ degrees higher than the refrigerant temperature on the low side.
 2. The evaporator surface temperature will depend on _____ and

REFRIGERATION COMPONENTS AND ACCESSORIES

OBJECTIVE

To help you to learn the purpose, principle of operation, maintenance requirements, location, and identification of refrigeration accessories.

INTRODUCTION

So far, you have studied the units that make up a basic refrigeration system. These are several other units that, if used correctly, will materially increase the efficiency or safety of the system. These units are called accessories. They are often advisable but not definitely required in a system. Each system must be considered individually before it can be determined if a given accessory will improve the efficiency of the system.

INFORMATION

The following assignments will be referenced from various chapters in the Modern Refrigeration and Air Conditioning textbook.

DIRECTED STUDY

ASSIGNMENT IN PREPARATION FOR DAY 14

I. Refrigeration Components

A. Read Paragraph 4-13

1. What is the purpose of the condenser?
2. Where is the heat picked up?
3. Domestic refrigerators commonly use four types of condensers. Name the four types.
4. To properly remove heat from the refrigerant vapor what must be accomplished with the condenser?

B. Read Paragraph 4-3

1. There are two pressure conditions in any compression refrigeration system. What are they?
2. Which components are located on the low side?
3. Which components are located on the high side?

C. Read Paragraph 15-54

1. The calculation of heat transfer capacity of a condenser is similar to what?
2. How fast must the condenser remove heat from the vapor?
3. Condensers may be divided into what 2 main types?

D. Read Paragraph 12-7

1. What type condensers are common in commercial systems?
2. How can the efficiency of an air cooled condenser be increased?

- E. Read Paragraph 12-8
1. Outdoor air-cooled condenser may have what units inside the building?
- F. Read Paragraph 12-9
1. Water cooled condensers are built in three styles. Name the three styles.
- G. Read Paragraph 12-10
1. In shell and tube condensers the water is in which unit and the refrigerant is in which unit?
- H. Read Paragraph 12-11
1. In shell and coil condenser where is the cooling water?
 2. How must this unit be cleaned?
- I. Read Paragraph 12-12
1. In the tube within a tube condenser where is the water? Where is the refrigerant?
- J. Read Paragraph 1-59
1. The word "Evaporator" is used to indicate what?
- K. Read Paragraph 4-5
1. Evaporators are mainly two types. What are they?
 2. Name the four different styles of evaporators.
- L. Read Paragraph 12-16
1. Into what two main groups are evaporators divided?
 2. Natural convection, air cooled evaporators fall into three classes or operating conditions. Name the three conditions.
- M. Read Paragraphs 4-14, 12-15
1. What is the purpose of the liquid receiver?
 2. According to figure 4-15 what are the two common types of receivers?
 3. Most receivers have what to prevent dirt entering the control valve?
 4. Receivers should have what type safety device installed?
- N. Read Paragraph 4-27
1. The original energy source for a reciprocating compressor is what?
 2. The rotary motion of the electric motor is changed to what?
 3. This change is usually made by what?
- O. Read Paragraph 4-41
1. Name the two basic types of rotary compressors.

P. Read Paragraph 4-46

1. The action that moves vapor outward is called what?
2. The pressure gained is _____ in a centrifugal compressor.
3. What is the chief advantage of the centrifugal compressor?

Q. Read Paragraph 7-13

1. When the motor and compressor are placed inside a dome or housing it is called what?

R. Read Paragraph 4-9

1. What is the purpose of the suction service valve?

S. Read Paragraph 4-11

1. What is the discharge service valve used for?
2. According to figure 4-11 what are the three positions for the service valve?

HOMEWORK IN PREPARATION FOR DAY 14

Read the following paragraphs from the Modern Refrigeration and Conditioning textbook. Be prepared to discuss material and answer questions on the assigned subject matter. Paragraphs 2-71, 2-72, 2-73, 4-24, 4-28, 4-30, 4-31, 4-33 thru 4-37, 4-42, 4-43, 4-46, 4-50, 9-1 thru 9-4, 9-29, 12-14, 12-17, 12-18, 12-19, 14-8

DIRECTED STUDY

ASSIGNMENT IN PREPARATION FOR DAY 15

I. Heat Exchangers, Oil Separators, Evaporators, Dessicants

A. Read Paragraph 12-35

1. Name the three advantages of a heat exchanger in the suction and liquid line.
2. A heat exchanger provides for what?
3. What is flash gas?
4. A heat exchanger also helps prevent _____ or _____ on the suction line.

B. Read Paragraph 4-12

1. Will a small amount of oil throughout the system harm it?
2. What happens if too much oil is pumped into components such as condenser, refrigerant controls, and evaporator?
3. Where is the oil separator installed?
4. Explain the operation of the oil separator.

5. Where are oil separators most commonly used?

C. Read Paragraph 14-49

1. Water removes heat from metal how many times more rapid than air?
2. Are water cooled condensers larger or smaller than air cooled condensers?
3. The condenser is designed to permit a water temperature rise of how many degrees?
4. How many degrees should be added to the water temperature to determine the refrigerant temperature?
5. The correct head pressure may now be determined how?
6. If head pressure is too high what should be done?
7. To determine if the trouble was air in the system or excess refrigerant what should be done?
8. If the pressure does not drop what should you do?
9. Excessive oil in the system is indicated by what?
10. A common water-cooled condenser problem is what?
11. What are the two operations for cleaning a condenser?
12. What safety precautions should be taken when working with sulphuric acid?

D. Read Paragraph 14-51

1. When a condenser or a receiver does not work properly, it is usually cheaper to do what?
2. If possible, what should you do to all joints to insure a lasting leakproof joint?
3. A welded condenser can be cut open, a new water coil installed and the shell re-welded. This is done only in an extreme emergency. Why?

E. Read Paragraph 14-52

1. In addition to mounting the condenser, brazing the joints and leak testing, on a water cooled unit what should be tested?
2. What should be done to all parts before assembly?

F. Read Paragraph 14-44

1. Which surfaces must be clean to insure good heat transfer?
2. If the air temperature or water temperature is above normal, what will happen to the condenser capacity?
3. If there is air in the system where will it collect?
4. High head pressure can be caused by four things. Name them.
5. For an overcharged condition when should the system be purged?

G. Read Paragraph 14-45

1. To find the temperature of the refrigerant what should be added to the air temperature?
2. If pressure is below normal what is the possible cause?
3. Most commercial air-cooled condensers are what type?

H. Read Paragraph 14-46

1. If a condenser needs replacing or is leaking what must be done with it?
2. When removing refrigerant from a condenser what safety precautions should be taken?
3. Fans, fan brackets, belts and motors may need to be removed on some units when removing the condenser, what should be done with these parts?
4. If electrical connections are removed, what should you do with them?
5. Why should wood or cardboard protectors be taped over the corners of the fins when removing a condenser?

I. Read Paragraph 25-35

1. Name five common dessicants.
2. Most driers will remove what from the refrigerant?
3. Why should a drier be installed in a cool place?
4. Following a burnout, a large capacity drier is usually placed where?
5. When should this drier be removed?

HOMEWORK IN PREPARATION FOR DAY 15

Read the following paragraphs from the Modern Refrigeration and Air Conditioning Textbook. Be prepared to discuss material and answer questions on the assigned material. Paragraphs 9-21, 9-22, 9-23, 9-24, 9-25, 9-26, 11-46, 14-47, 14-53, 15-43

BASIC REFRIGERATION

OBJECTIVE

To help you learn the basic operation of a simple refrigeration system; to teach you to assemble the system; and to practice procedures for changing and checking the system for leaks.

INTRODUCTION

A simple refrigeration system is composed of four basic components: compressor, condenser, refrigerant control, and the evaporator.

The proper installation of these components is necessary to obtain a satisfactory and trouble-free operation.

INFORMATION

The following assignments will be referenced from various chapters in the Modern Refrigeration and Air Conditioning textbook.

DIRECTED STUDY

ASSIGNMENT IN PREPARATION FOR DAY 16

I. Refrigeration Equipment

A. Read Paragraph 12-69

1. Where in the refrigeration system should the sight glass be installed?
2. When will the sight glass indicate bubbles?
3. Sight glasses may be installed _____ or _____.

B. Read Paragraph 12-70

1. If moisture is present in a system charged with R-11, R-12, R-13, R-113 and R-114, the chemical substance in a moisture indicator will turn _____.
2. What will happen to the moisture indicator if too much alcohol is placed in a system?

C. Read Paragraph 14-30

1. At _____, bubbles will appear regardless of the amount of refrigerant in the system.
2. Lack of refrigerant is likely due to a _____ in the equipment.

D. Read Paragraph 4-15

1. In common practice where is a filter drier installed?
2. Filters remove what from the system?

E. Read Paragraph 11-53

1. A drier-filter should be replaced when?
2. A filter-drier has an _____ stamped or cast on the body to indicate the _____ refrigerant should flow through it.
3. Filter-driers may be installed how in a system?

F. Read Paragraph 12-71

1. Practically all _____ and _____ must be removed or trapped where they can do no harm.
2. One design of liquid line driers allows the _____ to stay in the line. Only the _____ need be changed.
3. Name the most common dessicants.

G. Read Paragraph 14-47

1. When repairing a condenser, though it's usually cheaper to replace it, what is the first thing you should do?
2. If a tube is cracked what should be done?
3. To test a condenser what should be done?

H. Read Paragraph 14-48

1. What should be protected when installing a condenser?
2. Why should fittings be aligned?
3. In installing a condenser, no leaks are found, what now should be done?

I. Read Paragraph 14-42

1. Before installing a compressor what should be done?
2. Compressor and motor must be carefully _____.
3. The belt should be tight enough to allow one inch of belt deflection with how much force?

HOMEWORK IN PREPARATION FOR DAY 16

Read the following paragraphs from the Modern Refrigeration and Air Conditioning Textbook. Be prepared to discuss material and answer questions on the assigned material. Read Paragraphs 12-66, 12-67, 12-72, 12-74, 14-3, 14-50, 11-60, 11-61, 14-109

DIRECTED STUDY

ASSIGNMENT IN PREPARATION FOR DAY 17

I. Leak Checks

A. Read Paragraph 11-38

1. All methods of testing for leaks have one procedure in common, what is it?
2. Why should a leak check be performed prior to evacuation?
3. Many companies recommend using what to test for leaks?
4. After repairing a leak it is important to recheck the complete unit. Why?

B. Read Paragraph 11-27

1. To check pressure in a system, gauges must be connected to the system without allowing _____, _____ or _____ to enter.

2. A system with _____ service valve is easiest for attaching gauges.
 3. This system also permits one to check what?
 4. When connecting a MGA the lines, gauges and manifold must be kept free of what?
 5. The manifold should be purged with what?
- C. Read Paragraph 14-7
1. A big help to the service technician is what?
 2. This piece of equipment is used to check what?
 3. What are the parts of a manifold gauge assembly?
 4. Lines from the manifold are attached to where on the compressor?
 5. What positions are the manifold valves for charging?
- D. Read Paragraph 14-9
1. After a system is assembled you should do what?
 2. What are two methods for testing for leaks?
 3. Never use what gases to check for leaks?
 4. Leak tests should include what parts of system?
- E. Read Paragraph 11-40
1. Name the most common type leak detectors.
- F. Read Paragraph 11-41
2. The soap bubble method of leak detection used what?
 3. What is the weak point of using soap bubbles?
 4. The halide torch and electronic leak detectors are difficult to use around what type insulation?
- G. Read Paragraph 11-42
1. What are the three gases used in a halide detector?
 2. Explain how the halide torch works.
- H. Read Paragraph 11-43
1. The dielectric type electronic leak detector measures what?
 2. Which type leak detector is the most sensitive?
 3. The sniffer of electronic leak detector should be placed where when checking for leaks?
- I. Read Paragraph 11-44
1. To repair a leak, what must be done with the refrigerant in the system?
 2. Refrigerant should not be in a system when soldering or brazing why?

3. Leaks may start where in a system?
 4. Leaks are most often found where?
 5. What is the best procedure to take for a leak at a fitting?
- J. Read Paragraph 2-72
1. What is meant by purging a system?
- K. Read Paragraph 11-75
1. What is meant by evacuating a system?
 2. When is a system evacuated?
 3. What are the two different methods of evacuation?
 4. How many inches of mercury is drawn on a triple vacuum?
 5. Which type of evacuation will not remove all the moisture?
 6. The most careful _____ and _____ will not clean a unit that was carelessly put together with dirt in the system.
- L. Read Paragraph 11-76
1. What are the two main types of vacuum pumps?
- M. Read Paragraph 14-12
1. What are the two basic methods used to charge a system?
 2. When a system is charged using the low side, which is used vapor or liquid refrigerant?
 3. What may be used to speed the evaporation when charging?
 4. What may happen if low side pressure is too high when charging?
 5. What may happen if low side pressure is too low?
 6. Why is it important that liquid refrigerant not be allowed to reach the compressor?

HOMEWORK IN PREPARATION FOR DAY 17

Read the following paragraphs from the Modern Refrigeration and Air Conditioning textbook. Be prepared to discuss material and answer questions on the assigned material. Paragraphs 11-28, 11-29, 11-30, 14-32, 14-10, 11-45, 11-77

COMPRESSOR CHECKS AND TROUBLE ANALYSIS

OBJECTIVE

To familiarize you with the steps and procedures for refrigeration system maintenance.

INTRODUCTION

Careful attention to details and good workmanship pay dividends in better appearance and operation. Each installation should be carefully planned and sketched and a list of materials should be compiled. These steps will save time and prevent costly changes on the job.

After the refrigeration system has been assembled, all the air must be removed, the entire installation must be tested for leaks, and the proper amount of refrigerant must be added. The success or failure of the installation depends on the thoroughness and the care with which these things are accomplished.

INFORMATION

The following assignments will be referenced from various chapters in the Modern Refrigeration and Air Conditioning textbook.

DIRECTED STUDY

ASSIGNMENT IN PREPARATION FOR DAY 18

I. Replacement of Compressor Parts

A. Read Paragraph 14-31

1. What are the five general steps to follow when removing any part from a system?

B. Read Paragraph 14-34

1. When replacing a suction service valve, you must _____ all the refrigerant from the evaporator.
2. To remove a discharge service valve or a liquid receiver, what is done with the system refrigerant?
3. What precaution should be taken when a system is opened?

C. Read Paragraph 14-35

1. Why should you never rest the compressor weight on the flywheel?
2. Why should the flywheel be removed before removing the compressor?
3. What can be used to remove the flywheel?
4. When lifting a compressor the service technician should avoid what?

D. Read Paragraph 14-37

1. Name the 3 types compressor bearings?
2. How are old bearing sleeves removed?
3. Bushings pressed in a blind hole can be removed how?
4. Always measure a crankshaft at the journals for what?

5. A common source of noise in a compressor is _____.
6. Badly scored eccentric connecting rod bearings must be _____.

E. Read Paragraph 14-38

1. A leaky crankshaft seal may be caused by what?
2. How may you detect a leaky seal?
3. A leaky seal in a system using above atmospheric low-side pressure will cause what?
4. The visual symptoms of question 3 are what?
5. List the 4 steps for installing a replacement seal.

F. Read Paragraph 14-39

1. A defective valve plate is discovered. If a new one is available what would you do?
2. May discs or reeds be repaired?
3. What is coking?
4. What causes coking?

G. Read Paragraph 14-40

1. Why should new gaskets be used when assembling a compressor?
2. If a gasket is too thick what will be the result?
3. If a gasket is too thin what will result?
4. When a compressor is overhauled, should new or old oil be used?
5. What is the maximum amount of crankshaft end play allowable?

H. Read Paragraph 14-41

1. After a compressor has been repaired, what should be done with it?
2. How many methods can be used to test for leaks on repaired compressors?
3. Exhaust valve leaks can be located in how many ways?
4. Compressor efficiency is checked best by what?

HOMEWORK IN PREPARATION FOR DAY 18

Read the following paragraphs from Modern Refrigeration and Air Conditioning textbook. Be prepared to discuss and answer questions on assigned material. Paragraphs 4-38, 4-39, 4-40, 4-52, 4-53, 4-54, 4-55, 4-56, 4-57, 4-58, 4-59, 4-61, 14-36

DIRECTED STUDY

ASSIGNMENT IN PREPARATION FOR DAY 19

I. Service compressor, operate trainer, inspect accessories

A. Read Paragraph 9-31

1. Oil circulates through the system with the _____.
2. Why must oil be used in a compressor?

3. What are the five properties of a good oil?
4. Oil removed from a system should be _____.
5. When impurities are discovered in oil what action should we take?
6. Only oil recommended by whom will be used?

B. Read Paragraph 9-32

1. Moisture in the system may freeze where in the system?
2. Moisture in some systems may cause the refrigerant to break down and form what?
3. This breakdown may cause what?
4. Refrigerants must be kept in a sealed container and kept completely _____.
5. When servicing, avoid exposing cold internal parts of the system to what?
6. When internal parts are exposed what will happen?

C. Read Paragraph 11-47

1. A lack of oil in a system will do what to the mechanism?
2. An overcharge of oil will cause what?
3. On a service call add oil only when?
4. If the system has a low side leak, what may happen?
5. If you had a low side leak, what should be done with the oil?
6. How much oil should be replaced?

D. Read Paragraph 14-84

1. All the oil and the oil transfer equipment must be _____ and _____.
2. When adding oil by a rapid means why is it important that some oil be in the glass container?
3. Using the second method of adding oil to a crankcase, how do we add oil?

E. Read Paragraph 14-33

1. In cases of refrigeration failure, check which component first? Why?
2. What are two most common causes of compressor failure?
3. Noisy valves and worn piston can be detected by what?
4. An intake valve leak is indicated by what?
5. A seal leak is usually noticeable by what?

HOMEWORK IN PREPARATION FOR DAY 19

Read the following paragraphs from Modern Refrigeration and Air Conditioning textbook. Be prepared to discuss and answer questions on assigned material. Paragraphs 4-6, 4-7, 14-28, 14-81, 22-26

DIRECTED STUDY

ASSIGNMENT IN PREPARATION FOR DAY 20

I. Equipment Maintenance and Troubleshooting

A. Read Paragraph 11-12

1. Most outside noise in the refrigerator comes from what?

B. Read Paragraph 11-16

1. Large amounts of ice build up act as what?
2. The cause of ice build up is usually caused by what?
3. What can we check to see if the gasket is tight enough on the door?

C. Read Paragraph 11-50

1. The most costly service repair is what?
2. The fault of a motor compressor can be two things. What are they?
3. If system starts and operates correctly using manually start electrical connections, the problem is what?
4. If the electrical system operates correctly, then the compressor may not be _____.
5. The best check of a motor compressor is what?

D. Read Paragraph 11-34

1. A service technician should be able to locate the causes of almost every problem with what?

E. Read Paragraph 11-35

1. When moisture forms ice at the refrigerant control the system will completely _____.
2. If ice forms at the refrigerant control closing the refrigerant control the compound gauge will show what?
3. The moisture may be removed how?

F. Read Paragraph 11-36

1. Refrigeration oil has had what done to it?
2. Some wax may be separated from the oil at what point?
3. Why does this happen?
4. When wax separates at the refrigerant control what occurs with the low pressure?
5. The only remedy for this clogging is to do what?

G. Read Paragraph 11-37

1. A common source of poor refrigeration is what?
2. A below normal low side pressure and below normal high side pressure is an indication of what?

H. Read Paragraph 3-42 - 3-43

1. A defective service cord can cause the unit to do what?
2. What will be the corrective remedy?
3. Warm or hot foods placed in the cabinet will cause the unit to do what?
4. What will be the corrective action?
5. A fan motor not running will cause what trouble?
6. What corrective action should be taken?
7. A poor door seal will cause the unit to do what?
8. You have insufficient oil in the unit, what will be the trouble?
9. What corrective action should be taken?
10. A common cause of moisture in the refrigerator is noted. What is the trouble?

HOMEWORK IN PREPARATION FOR DAY 20

Read the following paragraphs from Modern Refrigeration and Air Conditioning textbook. Be prepared to discuss and answer questions on assigned material. Paragraphs 1-53, 7-31, 11-13, 11-14, 11-15, 11-17, 11-18, 11-19, 11-20, 11-21, 11-22, 11-23, 11-24

Technical Training

Refrigeration and Cryogenics Specialist

FUNDAMENTALS

October 1983



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REFRIGERATION LINES AND TUBING FABRICATION

PART 1

(Day 11)

OBJECTIVE

Given an assortment of copper tubing/pipe, identify the tubing/pipe by size and type with 80% accuracy. You will be allowed approximately 30 minutes to complete this objective.

PROCEDURE

IDENTIFYING COPPER TUBING

1. The tubing samples on the bench are numbered. Identify each sample by writing the type and size opposite the number that corresponds to the tubing sample. Under application, list when or where the tubing should be used.

SAMPLE NO.	TYPE	SIZE	APPLICATION
1			
2			
3			
4			
5			

2. Refrigeration tubing is sized by _____.

PART 2

OBJECTIVE:

Given a ruler, tubing cutter, tubing bender, and a roll of copper tubing, measure, cut, and bend tubing to an operational configuration without personal injury or equipment damage. Finished tubing must conform to instructor's template $\pm 1/8"$. You will be allowed approximately 30 minutes to complete this criterion.

PROCEDURE

CUTTING AND BENDING TUBING

CUTTING

1. Select a roll of 3/8-inch copper tubing.
 2. Unroll approximately two feet of the tubing, cut a piece approximately twelve inches.
 3. From this piece, measure and mark the tubing eight inches from the end.
 4. Install the tubing cutter so that the cutter wheel is over the mark.
 5. If a tube cutter is not available, what may be used to cut the tubing?
-
6. Tighten the cutter wheel slightly ($1/4$ turn) against the tubing and revolve the cutter slowly around the tubing.
 7. Continue revolving cutter, tightening slightly (approximately $1/4$ turn: after each turn until the tube is cut through).

CAUTION: Be careful not to drop the cutter and tube when the cut is completed.

8. Remove the cutter and insert reamer in the end of the tubing. Revolve the reamer until the burr is removed from the inside of the tubing.
9. Inspect the tube. If it is still rough on the end, smooth it very lightly with reamer.

NOTE: The reaming procedures should be done with the open end of the tube pointing down so the filings will not fall into the tube.

BENDING TUBING 180°

1. Measure the exact center of the piece you have cut off and mark. It should be four inches. This is known as the "Center Mark".
2. To make a 180° bend and have the legs of the bend the same length, measure back to the left of the center mark $15/16$ of an inch and mark. This is known as the "Start Mark".
3. Select the correct tube bender for 3/8-inch tubing.
4. Find the radius of the mandrel (that part of the bender which the tubing is bent around). Locate the "R" index mark on the top handle of tube bender and the "O" index mark on the mandrel.
5. Insert tubing into bender, making sure long part of the tubing extends to your right. Place tubing lock on tubing.

6. Align "R" index mark on tube bender handle, start mark on tubing, and "O" index mark on mandrel.
7. Bring handle down until "R" index mark and 180° index mark are aligned.
8. Remove tubing from bender.
9. Check the bend for accuracy.
10. Have the Instructor check your work.
11. To make a 90° bend, follow above procedures, except step 2. Measure back 1/4-inch from center mark and mark your start mark. When making 90° bend, bring handle down until "R" and 90° index marks are aligned.

OBJECTIVE

Using a ruler and an assortment of refrigeration fittings, identify one of each type by size and type with no more than one error. You will be allowed approximately 30 minutes to complete this objective.

PROCEDURE

IDENTIFYING REFRIGERATION FITTINGS

1. Identify the following illustrated fittings by writing in the correct nomenclature in the spaces provided.

Example:

- a. Fitting, refrigeration, brass,

Half-Union Reducer, 3/8"

Flare to 1/2" MPT

- b. Fitting, refrigeration, copper,

- c. Fitting, refrigeration, brass,

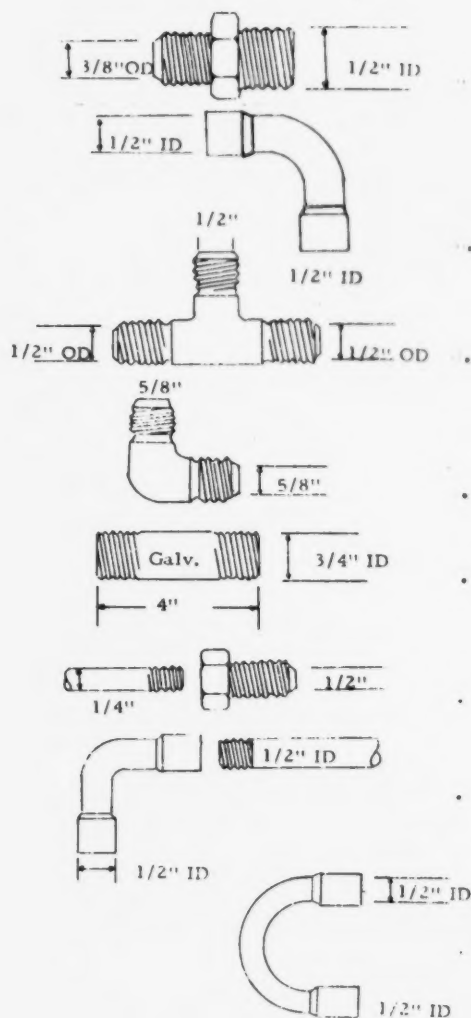
- d. Fitting, refrigeration, brass,

- e. Fitting, pipe,

- f. Fitting, refrigeration, brass,

- g. Fitting, refrigeration, brass,

- h. Fitting, refrigeration, cooper,



2. Complete the following statements regarding refrigeration fittings and measurement.

a. Name the three main types of refrigeration fittings.

_____, _____
_____.

b. Name the two types of flare nuts.

_____, _____

c. Explain how the following fittings are measured:

Sweat _____

Flared _____

Pipe _____

3. Identify each of the fittings provided you (numbered 1 through 5) according to type and size.

NUMBER	TYPE	SIZE
1		
2		
3		
4		
5		

(Day 11)

OBJECTIVE

With instructor assistance and using a ruler, tubing cutter, flaring kit, and copper tubing, measure, cut, flare, and swage tubing to a rough operational condition. Swage will be suitable for a solder connection. You will be allowed approximately 1 1/2 hours to complete this objective.

PROCEDURE

FLARING AND SWAGING COPPER TUBING

Flaring

1. Remove the burrs from one end of the 90° bend.
2. Place a 3/8-inch flare nut on the tubing.
3. Place the tubing in the flaring block (see figure 1).

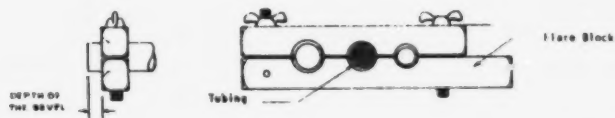


Figure 1. Tube Installed in Flare Block

NOTE: The tubing should extend above the flaring block a distance equal to one-third of the height of the flare. (Figure 2-17, page 43, Modern Refrigeration textbook).

4. Tighten the wing nuts on the flare block as tight as possible with your fingers.
5. Insert the flaring yoke over the flare block (see figure 2).

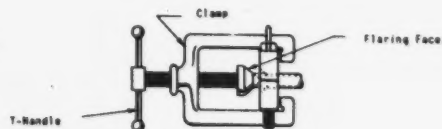


Figure 2. Flaring Yoke

1-6

6. Tighten T-handle 3/4 turn moving the flaring face into the end of the tubing and then loosen. Continue this procedure until the flare is completed.
7. Remove the flaring yoke.
8. Loosen the wing nuts and remove the tubing.
9. Have the Instructor check your work.
10. To fabricate a flare on the opposite end of the 90° bend, follow the above procedures.

Swaging Cooper Tubing

1. Ream both ends of the 180° copper bend.
2. Insert one piece of the copper tubing in the swaging block as illustrated in figure 3.

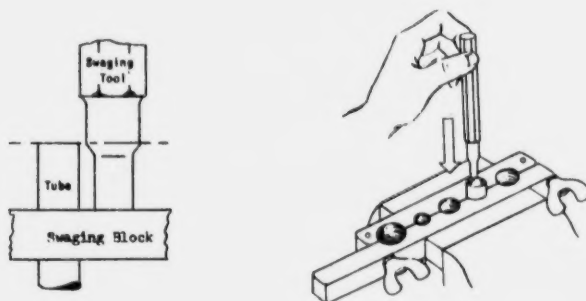


Figure 3. Swaging Block

3. Insert the proper size swaging tool in the tubing as illustrated in figure 4.
4. Use light strokes with a ball-peen hammer and drive the swaging tool into the tubing.

NOTE: The swaging tool should be turned slightly after each stroke.

5. Remove the swaging tool.
6. Remove the tubing from the swaging block.
7. Have the Instructor check your work.
8. To fabricate a swage on the opposite end of the 180° bend, repeat steps 2 through 7.

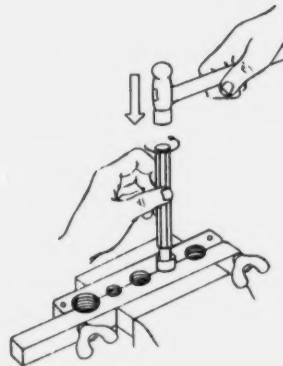


Figure 4.

SOLDERING AND BRAZING

(Day 12)

OBJECTIVE

With instructor assistance and using the hydrocarbon torch, soft solder a copper swage joint with at least 75% penetration, with no excess inside of joint, observing safety precautions for flammables. You will be allowed approximately 1 1/2 hours to complete this criterion.

PROCEDURE

AIR-ACETYLENE TORCH

SETTING UP AND LIGHTING THE TORCH

1. Turn the pressure adjusting screw of the regulator assembly (E, Figure 5) counterclockwise, all the way out, to place the diaphragm-type valve in a closed position.
2. Connect regulator (B), with hose assembly (C) and tip (D) attached, to the tank. Tighten the nut securely with a wrench.
3. Open the tank valve (A) 1/4 turn. Use a tank key and leave it on the tank.
4. Set the pressure adjusting screw for the approximate pressure desired.
5. Light the torch (use a friction lighter).
6. Readjust the regulator pressure adjusting screw to get the desired flame size.
7. To shut off the torch, close the tank valve.

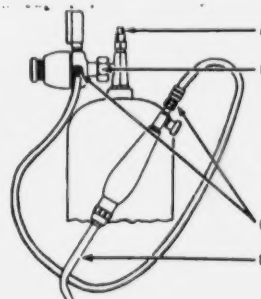


Figure 5.

SOFT SOLDERING

PREPARING COPPER FOR SOLDERING

1. Thoroughly clean both surfaces that are to be joined.

NOTE: Metal surfaces must be cleaned extremely well before they will soft-solder correctly. The surfaces should be cleaned with steel wool or fine sandpaper or a file may cut into the metal and cause a weak joint.

2. Apply a noncorrosive/non-acid flux (salve type) to the cleaned area.

CAUTION: This flux is very irritating to the eyes. Do not rub your eyes with fingers after getting flux on them.

NOTE: Do not apply the flux too thickly as excess flux may form bubbles when heated and prevent the solder from flowing into the joint.

3. After the tube has been inserted into the fitting, revolve it once or twice to spread the flux evenly.
4. Light the air-acetylene torch and adjust flame for soft soldering.
5. Apply the flame to one side of the fitting.

6. Occasionally test the heat by touching the fitting with the solder.

CAUTION: Do not let the flame touch the solder.

7. Remove the flame and apply solder to the opposite side of fitting from flame.

NOTE: Most beginning personnel have a tendency to use too much heat and too much solder.

8. Turn off the air-acetylene torch.

CAUTION: Lift hot tubing with pliers and cool in water bucket on the workbench.

9. Have the Instructor check your work.

10. The Instructor will have you cut your completed joint to check the condition of the soldered surfaces.

PART 2

(Day 12)

OBJECTIVE

With instructor assistance and using a hydrocarbon torch, hard solder a copper swage with at least 75% penetration, with no excess inside of joint. You will be allowed approximately 30 minutes for this criterion.

PROCEDURE

HARD SOLDERING USING SIL-FOSS

PREPARING COPPER FOR SOLDERING

1. Thoroughly clean both surfaces that are to be joined.

NOTE: Metal surfaces must be cleaned extremely well before they will solder correctly. The surfaces should be cleaned with steel wool or fine sandpaper. Rough sandpaper or a file may cut into the metal and cause a weak joint.

NOTE: Sil-Foss does not require flux.

2. After the tube has been inserted into the fitting, light the air-acetylene torch and adjust flame for hard soldering.
3. As the copper fitting begins to turn cherry red, touch the hard solder to the fitting on the opposite side if the flame.

CAUTION: Do not let the flame touch the solder. The metal must be hot enough to melt the solder.

4. Turn off the air-acetylene torch.

CAUTION: Lift hot tubing with pliers and cool in water.

5. Have the Instructor check your work.
6. The Instructor will have you cut your completed joint to check the condition of the soldered surfaces.

PART 3

(Day 12)

OBJECTIVE

With instructor assistance and using the hydrocarbon torch and aluminum repair kit provided, make a simple repair to damaged aluminum tubing. The repair material must adhere to the aluminum and must be of the approximate color to indicate a leak proof repair. You will be allowed approximately 30 minutes to complete this criterion.

PROCEDURES

ALUMINUM REPAIR KIT HOT PATCH

1. Locate leak on tubing.
2. Clean damaged area on tubing, using steel wool or sandpaper (and/or aluminum cleaning solvent).
3. Mix equal parts of resin and hardener on a disposable item (wood, paper).
4. When thoroughly mixed, apply to damaged tubing.
5. Double thickness application is advisable.
6. Light the air-acetylene torch and adjust flame for a soft flame.
7. Apply the flame to aluminum tubing.

CAUTION: Use touch-and-go method. Do not let the flame come in contact with the epoxy patch.

8. Remove flame when epoxy changes color (or as otherwise directed by manufacturer of the epoxy).
9. Turn off air-acetylene torch. Allow tubing to cool.
10. Have Instructor check your work.

HEAT STICK

1. Locate leak on tubing.
2. Clean area to be repaired, using steel wool or sandpaper.
3. Using the air-acetylene torch, heat area to be repaired until heat stick will flow.

CAUTION: Use touch-and-go method. Do not let the flame come in contact with the stick.

4. Cover the area to be repaired with heat stick.
5. Allow tubing to cool.
6. Have Instructor check your work.

PART 4

(Day 13)

OBJECTIVE

With instructor assistance and using the oxyacetylene torch, silver solder/braze a copper swage joint of each type, with at least 75% penetration with no excess inside the joint. You will be allowed approximately 2 hours to complete this criterion.

PROCEDURE

PREPARING OXYACETYLENE EQUIPMENT FOR USE

REVIEWING SAFETY PRECAUTIONS

Study the following safety precautions and observe them as you progress with the steps of this workbook.

1. Refer to oxygen and acetylene by their proper names.
2. Use cylinders in an upright position only.
3. Never use oil or grease on oxyacetylene equipment (FIRE HAZARD).
4. Provide adequate ventilation.
5. Do not release oxygen or acetylene in a confined space.
6. Do not use acetylene at pressures higher than 15 psi.
7. Turn off regulators before turning on gases from cylinders.
8. Close cylinder valves when leaving for an extended period.
9. Use a friction lighter to light torch.
10. Never leave a burning torch unattended.

ASSEMBLY OF EQUIPMENT

1. Locate the oxygen and the acetylene connections on the manifold.
2. Check outlet of both connecting valves, for any dust or foreign particles. If present, remove with a nonmetallic brush.
3. Attach the oxygen and acetylene regulators to their respective connections.

NOTE: The oxygen regulator connection has right-hand threads and the acetylene regulator has left-hand threads.
4. Secure the nuts with the wrench provided.

TESTING EQUIPMENT FOR LEAKS

1. Close torch handle valves, open manifold valves, and turn the regulator handles to the right to allow a little pressure to build up.

NOTE: Leaks can be detected by using soap solution (see figure 6).
2. Stop all leaks before going any further

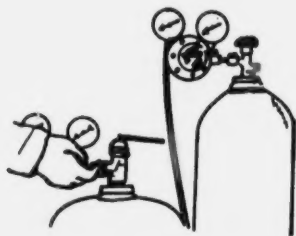


Figure 6. Checking for Leaks

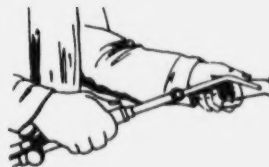


Figure 7. Lighting the Torch

LIGHTING TORCH

1. Adjust regulators to indicate pressures same as tip size.
2. Open the torch handle acetylene valve approximately 1/4 turn.
3. Light the gas flowing through the torch tip (see figure 7).
4. Open torch handle oxygen valve approximately 1/8 turn.
5. Open the acetylene valve until the base of the flame leaves the tip 1/16 inch.
6. Slowly open the oxygen valve until a carburizing flame is obtained.

SHUTTING OFF THE ACETYLENE TORCH

1. Shut off the acetylene torch valve.
2. Shut off the oxygen torch valve.
3. Close the acetylene manifold valve.
4. Open the acetylene torch valve allowing the acetylene to escape from the regulator and hose.
5. Turn the acetylene regulator adjusting screw counterclockwise until it turns easily.
6. Close the acetylene torch valve.
7. Close the oxygen manifold valve.
8. Open the oxygen torch valve allowing the oxygen to escape from the regulator and hose.
9. Turn the oxygen regulator adjusting screw counterclockwise until it turns freely.
10. Close the oxygen torch valve.
11. Return hoses and regulators to lockers provided.

SILVER BRAZING

1. Thoroughly clean the contacting surfaces of joints to be soldered.
2. Apply a silver soldering flux to the male fitting. (Paste Type)
3. Insert the male fitting into the swage and revolve it once or twice to spread the flux evenly.
4. Light the oxyacetylene torch and adjust to a carburizing flame.
5. Apply the flame evenly to one side of the swage bringing it to a cherry red.

NOTE: Silver solder melts at a temperature of 1000° to 1150°F.

6. Apply the solder to the top of the fitting on the opposite side from flame while applying heat near the bottom of the swage.

NOTE: If the heat is applied near the bottom of the swage, the solder will be drawn to the bottom.

7. Turn off the oxyacetylene torch.

CAUTION: Use pliers to handle hot metal, cool it in water bucket.

8. Cut the completed joint with a hacksaw and check for:

- a. Penetration.
- b. Excess flux.
- c. Oxidation.
- d. Excess solder.

9. Have the Instructor check your work.

SILVER BRAZING USING SIL-FOSS

1. Insert the male fitting into the swage.

NOTE: Sil-Foss soldering rod contains its own flux and cleaning agent. The tubing does not have to be cleaned or fluxed.

2. Light the oxyacetylene torch and adjust to a carburizing flame.
3. Apply the flame evenly to one side of the swage, bringing it to a cherry red.

NOTE: Sil-Foss soldering rod melts at a temperature of around 1250°F.

4. Apply the silver solder rod to the top of the fitting on the opposite side from flame, while applying heat near the bottom of the swage.

NOTE: If the heat is applied near the bottom of the swage, the solder will be drawn to the bottom.

5. Turn off the oxyacetylene torch.

CAUTION: Use pliers to lift hot metal and cool in water bucket.

6. Cut the completed joint with a hacksaw and check for:

- a. Penetration.
- b. Oxidation.
- c. Excess solder.

7. Have the Instructor check your work.

PRINCIPLES OF PHYSICS

PART 1

(Day 13)

OBJECTIVE

Given a commercial text, complete the assigned factual statements involving the principles of physics with 80% accuracy. You will be allowed approximately 1 hour to complete this objective.

PROCEDURE

Answer the following questions from your commercial text.

1. Paragraphs 1-3, 1-4. Heat is a form _____
Heat always flows from _____

Paragraph 1-5. A refrigerator gets cold by doing what with the heat?

2. Paragraph 28-62. Boyle's law states that if a pressure is applied to a gas in a cylinder then the volume will increase/decrease.

If an aerosol can is emptied in this classroom, will the volume of the gas leaving the can increase or decrease?

3. Paragraph 28-63. Charles's law states that if a bottle of gas is heated the pressure will increase/decrease.

If a cylinder of gas is emptied rapidly, will the cylinder become hot or cold?

4. Define sensible heat. _____

5. Define latent heat. _____

6. Name the three methods of heat transfer. _____

7. What is superheat?

What is sub-cooling?

8. Define pressure.

9. Define a vacuum.

10. Name the four major components of a refrigeration system.

- a. _____
- b. _____
- c. _____
- d. _____

PART 2

(Day 14)

OBJECTIVE

Given a PT chart, explain the pressure-temperature relationship for different refrigerants at various temperatures/pressures with 80% accuracy. You will be allowed approximately 1 hour to complete this objective.

PROCEDURE:

1. Define refrigerant.

2. Name five characteristics of Halo-Carbon refrigerant.

.....
.....
.....
.....

3. The ambient temperature is 85°F, using forced air and R-12 what should your discharge pressure be?

.....

4. The ambient temperature is 100°F, using forced air and R-11 what should your discharge temperature be?

.....
.....

5. Your MGA indicates 15 pounds pressure. Using R-12 what would be the temperature of your refrigerant on the low side?

.....

METRIC CONVERSIONS

Using the formula shown on page 12 of the Modern Refrigeration and Air Conditioning textbook, complete the following problems.

1. Convert a Fahrenheit temperature of 80° to centigrade (Celsius).

.....

2. Convert a Celsius temperature of 15° to a Fahrenheit temperature.

.....

REFRIGERATION COMPONENTS AND ACCESSORIES

PART I

OBJECTIVE

Given a list of five principles, select the ones which define the operating principles of the compression refrigeration cycle. One error permitted. You will be allowed 10 minutes to complete this objective.

PROCEDURE

In the space provided indicate whether the statement is true or false.

- _____ In the compression refrigeration cycle compression takes place on the down stroke of the piston.
- _____ HPHT gas is charged to HPHT liquid in the condenser by desuperheating, condensing, and subcooling.
- _____ The evaporator removes heat from the refrigerated space.
- _____ The refrigerant control meters refrigerant into the evaporator.
- _____ The purpose of the condenser is to get rid of heat picked up in the evaporator.

PART 2

(Day 14)

OBJECTIVE

Given the names of three refrigeration components, explain the basic types, purpose, and principle of operation for each component with a total of no more than three errors. You will be allowed approximately 25 minutes to complete this objective.

PROCEDURE

Using the text references and/or instructor furnished information, answer the following questions concerning the types, purposes, and principles of operation of the condenser, evaporator, and receiver.

1. Condenser

- a. Condensers are typed according to the cooling medium used. The two major types are _____ cooled and _____ cooled.
- b. Regardless of type or design, the purpose of the condenser is _____
- c. Briefly explain the principles of operation of the condenser.

2. Evaporator

- a. The purpose of the evaporator is _____

- b. The operating conditions (classes) of evaporators are:
(1) _____
(2) _____
(3) _____
- c. Explain the principles of operation of the evaporator.

3. Receiver

- a. Types of receivers are _____ and _____.
- b. Purpose of the receiver is _____ of refrigerant.
- c. What part of the receiver maintains liquid seal (allows only liquid refrigerant to go to the liquid line)?

PART 3

(Day 14)

OBJECTIVE

Given the names of three types of compressors, explain the basic operating principles of each with no more than two errors. You will be allowed approximately 25 minutes to complete this objective.

PROCEDURE

1. Reciprocating Compressor

- a. What is meant by reciprocating motion in a reciprocating compressor?

- b. In your own words explain the operating principles of a reciprocating compressor.

2. Rotary Compressor

- a. Name the two types rotary compressors.

- b. Where are the check valves in a rotary compressor?

- c. Explain how compression takes place in a rotary compressor.
-

3. Centrifugal Compressor

- a. What main advantage does a centrifugal compressor have?
-

- b. Explain how compression takes place in a centrifugal compressor.
-
-

PART 4

(Day 15)

OBJECTIVE

Given six basic facts stating the purpose, use, and operating principle of heat exchangers and oil separators, match the facts with the unit. No more than two errors permitted. You will be allowed approximately 15 minutes to complete this objective.

PROCEDURE

1. From the following statements, indicate which one is for heat exchangers and which one is for oil separators.

- _____ a. It reduces flash gas in the liquid line.
- _____ b. The purpose of this component is to maintain a full crankcase of oil.
- _____ c. Must be used when the condensor is above the evaporator.
- _____ d. Has a counter flow method of heat transfer.
- _____ e. This component increases the efficiency of a refrigeration unit.
- _____ f. Insulated to prevent refrigerant from condensing during off cycle.

(Day 15)

OBJECTIVE

List the steps required for servicing an evaporator, condenser, and oil separator with no more than two errors. You will be allowed approximately 1 hour to complete this objective.

PROCEDURE

1. A refrigerator is not cooling. It has been determined that refrigerant is escaping from the evaporator. List the steps required to service this unit.

2. An air cooled condenser has been found to be leaking. On initial inspection a cracked tube was noted and bent fins were discovered. List the steps required to service this condenser.

3. Troubleshooting procedures has indicted a faulty oil separator. Your supervisor has instructed you to obtain a serviceable oil separator and install it on the unit. What steps must be followed to service the oil separator before installation.

PART 6

(Day 15)

OBJECTIVE

Given a list of refrigerant equipment accessories and a list of basic facts related to them, match the facts to the accessories with 80% accuracy. You will be allowed approximately 30 minutes to complete this objective.

PROCEDURE

Match each accessory with its related characteristic.

- | | |
|--|-------|
| (1) Manifold gauge assembly | _____ |
| (2) Charging cylinder | _____ |
| (3) Storage cylinder | _____ |
| (4) Dolly | _____ |
| a. Used to evacuate system | _____ |
| b. Generally positioned upside down with valve on bottom | _____ |
| c. Used to move heavy items | _____ |
| d. Never recharge a disposable one | _____ |
| e. This cylinder carried by service technician | _____ |
| f. Used to move refrigerant cylinders | _____ |
| g. Refrigerant transferred from this cylinder to smaller one | _____ |
| h. Used to charge and discharge system | _____ |

PART 7

(Day 15)

OBJECTIVE

State the types, purpose, and use of desiccants with no more than two errors. You will be allowed 15 minutes to complete this objective.

PROCEDURE

1. From the most common types dessicants discussed, list three types.
 - a. _____
 - b. _____
 - c. _____
2. What is the purpose of dessicants?

3. Dessicants are used where in a refrigeration system?

BASIC REFRIGERATION

PART 1

(Day 16)

OBJECTIVE

Using a refrigeration trainer, copper tubing/pipe, and common hand tools and special tools provided, fabricate four refrigerant lines and install them. Three of the four must not have kinks or leaks. Clean the hand tools and replace them in the tool box. Only one error in selection, use, and maintenance of tools allowed. You will be allowed approximately 3 hours to complete this objective.

PROCEDURE

IDENTIFICATION OF REFRIGERATION SYSTEM COMPONENTS

1. Connect the trainer to the electrical power source. (INSTRUCTOR)
2. Operate the trainer. (INSTRUCTOR ONLY)
3. During the operation of the trainer, feel of both copper lines that are connected to the compressor.
4. The warm line is the _____.
5. The cool line is the _____.
6. Feel the air as it leaves the condenser.

CAUTION: DO NOT get your hand in the fan or drive belt!

7. Where did this heat come from originally?
- _____

8. Feel the air near the evaporator.
 9. Why does this air feel cool?
- _____

CONNECTING A SYSTEM

1. Study the arrangement of the components in Figure 8.
2. Place the name of each item in the numbered space provided.
3. Have the Instructor check your work.

STEPS FOR INSTALLING A MANIFOLD GAUGE ASSEMBLY

1. Close both manifold valves.
2. Remove the dust cover from both compressor service valves.

CAUTION: Clean the area before removing the dust covers and gauge port caps.

3. Place both compressor service valves in the back seat position by turning the valve stems counterclockwise.
4. Remove service valve gauge port cover caps.

5. Connect the low side gauge line of the manifold gauge assembly to the compressor suction service gauge port.

NOTE: All flexible line connections should be finger-tight only.

6. Connect the high side gauge line of the manifold gauge assembly to the compressor discharge service valve gauge port.
7. Place both compressor service valves in the gauge position (1/2 turn from back seat).
8. Slightly open each manifold valve momentarily and then close again to purge air and moisture from the flexible lines prior to operating the unit.

NOTE: TODAY YOU WILL PURGE ALL REFRIGERANT FROM THE SYSTEM SINCE YOU WILL BE ASSEMBLING THE SYSTEM UNITS (SEE PROCEDURE BELOW).

9. Ask the Instructor to check completed steps then proceed with the procedure below.

ASSEMBLING SYSTEM UNITS

1. Cut a piece of tubing the correct size and length to be used as a suction line (approximately 4 feet). What would an undersized suction line cause?

2. Remove the old suction line and install the new line between the suction service valve and the evaporator outlet. (Remove and reuse the same flare nuts if condition is good).

CAUTION: Do not over-tighten the flare nuts as the flare might be cut off.

What type of flare nut must be used at the evaporator outlet?

Why?

3. Why is it necessary to always slant the suction line down to the compressor?

4. Cut a piece of tubing the correct size and length to be used between the receiver and filter drier.

5. Fabricate and install this line.

6. Install filter drier.

7. Cut a piece of tubing the correct size and length to be used between the filter drier and sight glass.

8. Fabricate and install this line.

9. Install a sight glass between filter drier and evaporator.

NOTE: SIGHT GLASS SHOULD BE EASILY VIEWED FROM THE FRONT OF THE TRAINER. THE DOT SHOULD BE TO THE REAR.

10. Fabricate the liquid line from the sight glass to the inlet of the refrigerant control.

NOTE: Place a loop in this line.

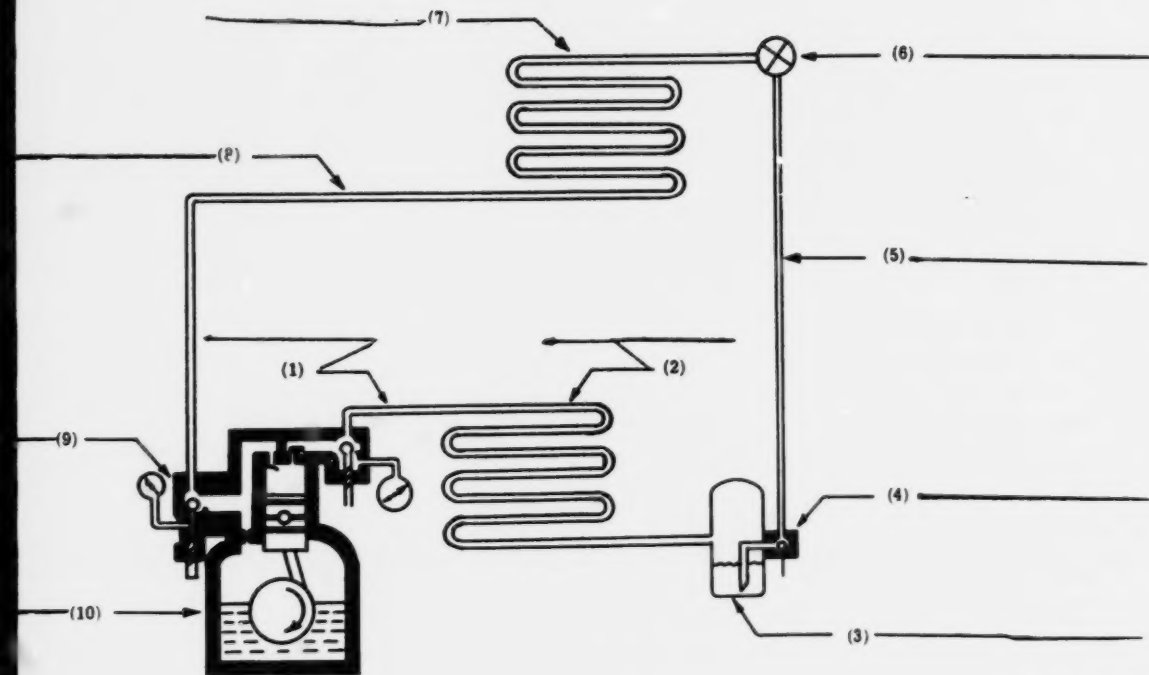


Figure 8

11. Why is this loop necessary? _____
12. Have the Instructor check your work.
13. Clean common hand tools and return to tool box. Return special tools to shelf in tool cabinet. Using paper towels and a cleaning agent, clean your working area.

PART 2

(Day 17)

OBJECTIVE

Given three randomly selected items of refrigeration equipment, list the steps for installing with no more than two errors. You will be allowed approximately 30 minutes to complete this objective.

PROCEDURE

1. Give the procedures for installing a sight glass.

2. Give the procedures for installing a filter dryer.

3. Give the procedures for installing a receiver.

4. Give the procedures for installing a condenser.

5. Give the procedures for installing a compressor.

PART 3

(Day 17)

OBJECTIVE

Using a refrigerant trainer, and equipment provided, locate and repair the refrigerant leaks with no more than one assist from the instructor. You will be allowed approximately 1 1/2 hours to complete this objective.

PROCEDURE

SERVICE VALVES

1. How many ports are there on one service valve?

2. Name each port that is on a service valve.

a. _____ b. _____ c. _____

3. What are the valve positions for service valves?

4. With the valve stem turned all the way in, what is the service valve position set in?

5. With the valve stem turned all the way out, what is the service valve position set in?

6. With the valve stem in the mid-way position between open and closed, what is the service valve position set in?

7. What is the backseated position used for?

8. Should the service valve be left in the backseated position?

9. What is the valve position for normal operation?

PROCEDURE

CHARGING FOR LEAK TEST

1. Install the manifold gauge assembly (manifold gauge valves should be closed, service valves should be back seated).

2. Place both compressor service valves in the gauge position. Why should the service valves be in the gauge position?

3. Connect the middle port of the manifold gauge assembly to a refrigerant cylinder using a flexible charging line. How tight should these connections be?

-
4. Put on safety goggles. Why is this step necessary?

CAUTION: Be sure that the refrigerant cylinder is in an upright position.

5. Open the refrigerant cylinder valve a minimum of 1/2 turn.
6. Loosen the middle flexible line connection at the manifold gauge assembly to purge the air out of the line.
7. Tighten the flexible line connection.
8. Open both manifold valves enough to let the refrigerant from the cylinder enter the system. Observe suction gauge, add refrigerant until a pressure of 15 to 35 psi is obtained.
9. Close both manifold gauge valves.
10. Close the refrigerant cylinder valve.
11. Have the Instructor check your work.

USING THE HALIDE LEAK DETECTOR

1. Open the needle valve slightly to start fuel gas flow.
2. Ignite the gas at the detector tip.
3. Using the needle valve, adjust the flame to about an inch above the reactor plate.
4. Observe the reactor plate until it becomes heated to a cherry red color.
5. Using the needle valve, readjust the flame to 5/8-inch above the reactor plate.
6. Explore for leaks by moving the end of the search hose around all joints and connections.

NOTE: The search hose must be moved slowly.

7. Observe the flame for a possible color change. A small leak will be indicated by a green flame. A large leak will be indicated by a purplish-blue flame.

CAUTION: Be careful of any phosgene gas that may develop.

8. Have the Instructor check your work.

SERVICE VALVES AND MGA VALVE POSITIONS

	SV		MGA		KV	REMARKS
	LOW	HIGH	LOW	HIGH		
1. Charge for leak check-----						
2. Evacuate system-----						
3. Charge for operation-----						
4. Normal operation-----						
5. Pump down system-----						
6. Oil check-----						
7. Suction valve check-----						
8. Discharge valve check-----						
9. Operational shaft seal check-----						
10. Equalizing shaft seal-----						
Using compressor for evacuation-----						

Checked by: _____
Instructor

PART 4

(Day 17)

OBJECTIVE

Using a simple refrigeration trainer and tools provided, purge, evacuate, charge, and pump down the system with no more than two assists from the instructor. You will be allowed approximately 1 hour to complete this objective.

PROCEDURE

EVACUATING PROCEDURES

1. Install the manifold gauge assembly.
2. Purge any refrigerant pressure from system.
3. Plug in the vacuum pump to a 110V outlet.
4. Remove the dust covers from BOTH the vacuum and exhaust fittings then connect the center flexible line to the vacuum pump.

CAUTION: Be sure to connect the hose to the correct fitting (vacuum) or the vacuum pump may be damaged.

5. Position the manifold gauge valves, service valves, and king valve for evacuation (service valves gauged, king valve open, hand valves open).

6. To start the vacuum pump, turn the start switch to the start position and then release. The switch will return to the run position.

CAUTION: IF THIS IS NOT DONE CORRECTLY, DAMAGE TO THE PUMP COULD RESULT.

7. Operate the vacuum pump until approximately 28" of mercury shows on the low side gauge.

8. Close both manifold gauge valves, then stop the vacuum pump.

NOTE: If system has a leak, the vacuum will not hold when the valves are closed. If the system has a leak, repair it and repeat steps 3, 4, 5, 6, and 7.

9. Have the Instructor check your work.

CHARGING A SYSTEM FOR OPERATION

Preoperational Check

1. Insure that trainer is unplugged.
2. Check for loose or frayed electrical wiring.
3. Check for loose or broken refrigeration lines.
4. Check pressure setting on high pressure control to ensure that it is not set above 200 psi.

Operational Check

1. Wear protective goggles.
2. Insure that both compressor service valves are in the gauge position.
3. Insure that the king valve is in the open position.
4. Plug trainer into the 110-volt outlet.
5. Insure tools are not in a position to fall into the condenser fan and compressor flywheel while trainer is in operation.
6. Connect a refrigerant cylinder to the center flexible line of the manifold gauge assembly.
7. Open cylinder valve 1/2 turn.
8. Purge the air from the charging line at the center port of the manifold gauge assembly.
9. Slightly open the low side manifold gauge assembly.
10. Start the compressor.
11. Adjust the low side manifold gauge valve to maintain approximately 40 psig on the compound gauge.
12. Observe the sight glass. What condition is indicated by bubbles in the sight glass?

CAUTION: DO NOT LEAVE YOUR TRAINER WHILE YOU ARE CHARGING.

13. As soon as bubbles in the sight glass disappear, close the low side manifold gauge valve to stop the charging process.
14. Let the refrigeration system operate for several minutes.

NOTE: If bubbles do not reappear, the unit is fully charged.

Post Operational Check

1. Close the refrigerant cylinder valve.
2. Remove the charging line from the refrigerant cylinder.
3. Remove your safety goggles.
4. Have Instructor check your work.

PUMP DOWN

1. Position all of valves for system pump down:
 - a. Compressor discharge service valve _____
 - b. Compressor suction service valve _____
 - c. Receiver valve (king valve) _____
 - d. High side manifold valve _____
 - e. Low side manifold valve _____
2. Operate the system until the compound gauge reading remains between 1 to 5 psig. The system is then pumped down.

NOTE: System may have to be started and stopped a number of times before pressure remains 1-5 psig.
3. Shutdown procedures:
 - a. Turn off system.
 - b. Unplug trainer from 110-volt power supply.
 - c. Back seat compressor service valves.
 - d. Purge and remove the manifold gauge assembly.
 - e. Install dust covers and port caps.
 - f. Clean unit.
4. Have Instructor check your work.

COMPRESSOR CHECKS AND TROUBLE ANALYSIS

PART 1

(Day 18)

OBJECTIVE

Given the information, list the steps required to replace four randomly selected parts of a compressor with no more than two errors. You will be allowed approximately 1 hour to complete this objective.

PROCEDURE

List replacement steps for four of the following listed compressor parts as indicated to you by your instructor (randomly selected).

1. List the steps required to replace the valves of a compressor.

2. List the steps required to replace a piston on a compressor.

3. List the steps required to replace the connecting rod of a compressor.

4. List the steps required to replace a crankshaft on a compressor.

5. List the steps required to replace the head on a compressor.

6. List the steps required to replace the service valves on a compressor.

7. List the steps required to replace the wrist pin on a compressor.

8. List the steps required to replace the shaft seals on a compressor.

PART 2

(Day 19)

OBJECTIVE

Given a small compressor and common hand tools, remove the compressor head and inspect and replace the valves with assistance from the instructor. You will be allowed approximately 30 minutes to complete this objective.

PROCEDURE

DISASSEMBLING A COMPRESSOR

1. Place the compressor in an upright position and remove the ten compressor head retaining bolts.
2. Remove the compressor head by tapping it lightly with a mallet.
3. Remove the valve plate and suction strainer.
4. Remove the suction valves.

REASSEMBLY OF COMPRESSOR

1. Lay out all parts that have been removed.
2. Inspect each item for evidence of wear, cracks, rough handling, etc.
3. Have the Instructor check each questionable item.
4. Discard rejected parts and procure new replacements as required.
5. Replace suction valves.

6. Replace valve plate.

CAUTION: Exercise extreme care when replacing the valves and valve plate on compressor.

NOTE: Hold the valve plate and line up the valve pins on compressor body with the holes in the valve plate. After getting everything lined up, tap the valve plate lightly with a mallet.

7. Replace compressor head.
8. Replace the ten compressor head bolts.

CAUTION: Do not over-tighten.

9. Have Instructor check your work.

PART 3

(Day 19)

OBJECTIVE

Given the oil and equipment required, service the compressor on a refrigeration trainer with instructor assistance. You will be allowed approximately 30 minutes to complete this objective.

PROCEDURE

COMPRESSOR OIL LEVEL CHECK

1. Install manifold gauge assembly.
2. Position all valves for normal operation.
3. Purge air from the manifold gauge assembly and flexible lines.
4. Operate the compressor until the compressor body is warm or until the refrigerant has been removed from the oil.
5. Turn off the compressor.
6. Front seat the suction service valve.
7. Pump the compressor crankcase down to between 1 to 5 psig, compound pressure gauge.

CAUTION: GOGGLES SHOULD BE WORN FOR THE NEXT STEP!

8. Remove the oil plug slowly.
9. Check the oil level in the compressor with a clean dip stick. Satisfactory oil level should range between 1 1/2 to 2 1/2 in depth of the dip stick.
- NOTE: In the field refer to manufacturer's or Air Force's technical manuals.
10. Add oil only if necessary.

NOTE: Do not add excessive oil to compressor. Excess oil will cause the compressor to pump oil and reduce compressor efficiency.

11. Replace oil plug loosely in the compressor.
12. Crack the compressor suction service valve momentarily from the front seat position to purge air from the compressor crankcase.
13. Tighten the oil plug. Use 3/4" box-end wrench.

14. Return the compressor suction service valve to the gauge position.
15. Clean up your work area of any spilled oil.
16. Have the Instructor check your work.

PART 4

(Day 19)

OBJECTIVE

Using a refrigeration trainer, perform a preoperational check, position the king and service valves, and operate the system, using the MGA to confirm normal operation with instructor assistance. You will be allowed approximately 30 minutes to complete this objective.

OPERATIONAL CHECK

1. Record position of all valves for normal operation:
 - a. Compressor discharge service valve _____
 - b. Compressor suction service valve _____
 - c. Receiver valve (king valve) _____
 - d. Low side manifold valve _____
 - e. High side manifold valve _____
2. Install the manifold gauge assembly.
3. Operate the system until pressures and temperatures stabilize before proceeding to the next step.
4. Compute system head pressure.
 - a. Ambient air temperature is _____ °F.
 - b. Head pressure should be _____ psig.
 - c. Head pressure is _____ psig.
 - d. Is this pressure normal at this ambient temperature? _____
5. Note sight glass for refrigerant charge.
Sight glass indicates the system is _____.
6. Place thermometer on evaporator surface. Wait until temperature stabilizes. Compare converted thermometer reading with low side gauge.
 - a. Reading on thermometer is _____ °F.
 - b. Reading on compound gauge is _____ psig. Converted temperature reading for this psig is _____ °F.
 - c. If thermometer reading is different from the low side gauge, indication of what it should be, what is possible trouble?
_____, _____.
7. Check the ambient air temperature at the inlet of the condenser with a thermometer.
Temperature reading is _____ °F.

CAUTION: DO NOT TOUCH CONDENSER FAN BLADE WITH THERMOMETER OR HAND!

8. Check the ambient air temperature at the outlet of the condenser with a thermometer.

Temperature reading is _____°F.

9. Is the condenser transferring heat to the cooling medium?

Give reason: _____

10. Check the condition of the condenser.

a. Are the fins straight? _____

b. Is the surface clean? _____

c. Check security of mounting.

Results: _____

d. Check for restricted air flow.

Results: _____

11. Remove manifold gauge assembly.

12. Have the Instructor check your work.

PART 5

(Day 19)

OBJECTIVE

Using a refrigeration trainer, inspect the operation of the refrigeration components and accessories and the compressor for proper operation and rotation with instructor assistance. You will be allowed approximately 3 hours for completion of this objective.

PROCEDURES

A. SUCTION VALVE CHECK

1. Install the manifold gauge assembly.
2. Place all valves in the normal operation position.
3. Purge air from manifold gauge assembly and flexible lines.
4. Operate the unit until the compressor body feels warm to the hand or until the refrigerant has been removed from the oil.
5. Front seat the suction service valve.
6. Operate the system until the compressor pulls down to a 20" Hg vacuum.
7. Record the suction pressure reading. _____
8. If the compressor will not pull a minimum of 20" Hg, the suction valves are probably bad.

9. During normal operation, what would indicate a leaky suction valve?

10. Return the suction service valve to the gauge position.

11. Stop the compressor.

B. DISCHARGE VALVE CHECK

1. Be sure the compressor is NOT operating.

2. With the manifold gauge installed, front seat the discharge service valve and gauge the suction service valve.

CAUTION: EXCESSIVE HEAD PRESSURE CAN BLOW THE COMPRESSOR HEAD OFF IF THE HIGH PRESSURE SAFETY SWITCH FAILS!

3. Operate the compressor intermittently (ON and OFF) until a minimum of 150 psig pressure is indicated on the high pressure gauge.

4. Watch the high pressure gauge indicator needle closely. A rapid drop in pressure down to and below normal operational head pressure indicates a leaky discharge valve. A moderate drop in pressure with the needle stopping at normal operational head pressure indicates a good discharge valve.

5. Record your observation:

6. Your observation in step 5 indicates a _____ discharge valve.

7. Return the discharge service valve to the gauge position.

8. Have the Instructor check your work.

C. COMPRESSOR SHAFT SEAL CHECKS

1. OPERATIONAL CHECK

a. Install the manifold gauge assembly.

b. Position all valves for normal operation.

c. Operate the system for a minimum of five minutes.

d. Check the shaft seal with a Halide leak detector while the compressor operates.

CAUTION: BE CAREFUL OF ALL MOVING PARTS!

e. Watch color of flame for any change:

(a) Green -- small leak.

(b) Purplish-blue -- large leak.

- f. Record your observation:

2. EQUALIZED PRESSURE CHECK

- a. Turn off the compressor.
- b. Remove the center flexible line from the manifold gauge assembly.
- c. Cap the center port of the manifold gauge assembly with a compressor service valve gauge port cap. Leave this cap loose for purging.
- d. Open the high side manifold gauge assembly valve momentarily to purge air from the manifold gauge assembly.
- e. Tighten the cap on the manifold gauge assembly.
- f. Slightly open both manifold gauge assembly valves to bypass pressure from high to low side of the system.
- g. Note pressure readings on the compound and high pressure gauges. Both gauges should read equal pressure.
- h. Check the shaft seal with a Halide leak detector when pressures have equalized.
- i. Record your observations:

- j. Close both manifold gauge assembly valves.
- k. Carefully remove cap from the center manifold gauge assembly port and install center flexible line in its place.
- l. Have the Instructor check your work.

D. INSPECTION OF REFRIGERATION ACCESSORIES

1. Install the MGA.
2. Operate unit until pressures stabilize.
3. Check accessories for proper operation: sight glass, filter drier, accumulator.
4. Check high pressure safety switch for proper setting.

5. Shutdown procedures:

- (a) Turn off system.
- (b) Unplug trainer from 110-volt power supply.
- (c) Back seat compressor service valves.
- (d) Purge and remove the manifold gauge assembly.
- (e) Install port caps.
- (f) Place service valves in gauge position.
- (g) Install dust covers.
- (h) Clean unit.

6. Have Instructor check your work.

PART 6

(Day 20)

OBJECTIVE

Using a refrigeration trainer, troubleshoot the system and perform equipment maintenance with instructor assistance. You will be allowed approximately 4 hours to complete this objective.

PROCEDURE

- 1. Install manifold gauge assembly.
- 2. Operate system until temperatures and pressures stabilize.
- 3. Check system for normal operation.

NOTE: Correct any malfunction before proceeding.

- 4. Inform your Instructor when system is operating normally.
- 5. You will be given a project to do while a malfunction is placed in your system.
- 6. Operate system noting any abnormal readings. Troubleshoot your system until suspected malfunction is located.
 - a. Suspected malfunction _____.
 - b. Equipment maintenance to correct malfunction.

- 7. Check with Instructor. Perform maintenance as directed.
- 8. Remove MGA.
- 9. Shut down equipment.
- 10. Clean unit.

J3ABR54530 001-III-1 thru 3, 5, 6, and 8

Technical Training

Refrigeration and Cryogenics Specialist

METERING DEVICES, MOTOR CONTROLS,
DOMESTIC AND COMMERCIAL REFRIGERATION

October 1982



USAF TECHNICAL TRAINING SCHOOL
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

DESIGNED FOR ATC COURSE USE

DO NOT USE ON THE JOB

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DIRECTED STUDY ASSIGNMENTS

Complete Prior to Day:

21	-----Pages 1-1 thru 1-6
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Supersedes SGs J3ABR54530 001-III-1 and III-2, February 1981.

METERING DEVICES

OBJECTIVE

This Study Guide/Workbook will acquaint you with:

- ° The operating principle of capillary tubes, automatic and thermostatic expansion valves, and special metering devices.
- ° The procedures for removing, replacing and adjusting expansion valves.

INTRODUCTION

This Study Guide/Workbook will prepare you for the indicated days of instruction. You must complete the assignments and be prepared for evaluation at the beginning of each day.

DIRECTED STUDY AND HOMEWORK

Assignment in preparation for day 21:

I Metering Devices

Read the following paragraphs and answer the questions about them.

Any device used to control the amount of liquid refrigerant to the evaporator is called a refrigerant control or metering device.

Refrigerant controls are manufactured in two basic types.

- ° Pressure operated
- ° Temperature operated

Capillary tubes, metering orifices and automatic expansion valves are examples of pressure operated metering devices.

Thermostatic expansion valves are temperature operated metering devices.

- ° What are the two types or classifications of refrigerant controls?

_____ and _____.

A. Pressure operated refrigerant controls

1. Capillary tubes

Capillary tubes are primarily used in domestic refrigeration, central A/C and heat pumps. This type of control is simple, economical, and allows the use of a low starting torque motor. One end of the capillary tube is attached to the bottom of the condenser. You may find a strainer installed between the condenser and capillary tube. The capillary tube is soldered to the suction line to act as a heat exchanger and gives the capillary tube added strength, and terminates in an expansion chamber at the top of the evaporator.

- ° Capillary tubes are primarily used in _____,
_____ and _____.

- ° Capillary tubes are soldered to the suction line for two reasons. What are they? _____
_____ and _____.

PRINCIPLE OF OPERATION OF CAPILLARY TUBE. Liquid refrigerant with a pressure of 120 to 140 psi and a temperature of 90 to 120°F enters the capillary tube. (Pressures and temperatures are approximations.) As the liquid travels through the capillary tube, its pressure is reduced by the resistance of the tubing. At the same time, its temperature is being reduced by the cold suction line. These two forces continue to act on the liquid refrigerant as it proceeds through the capillary tube. However, the pressure is reduced (comparatively) faster than the temperature. At some point (usually within the last 1/3 of the tube) the pressure of the liquid refrigerant is reduced below its boiling point. Some of the liquid refrigerant "flashes" or boils. The vapor occupies more space than the liquid so the resistance to flow is increased. The temperature of the refrigerant is decreased by both the flashing of liquid and by the action of the cold suction line. The point where the flashing first occurs to the end of the capillary tube is known as a "vapor lock or bubble point."

All capillary tubes have a vapor lock. The length of the vapor lock depends on a combination of the following factors.

- * Condensing temperature.
- * Condensing pressure.
- * Amount of subcooling of the liquid in the condenser.
- * Temperature of the suction line.
- * Pressure difference between the low and high side.
- * The length and diameter of the capillary tube.

○ In your own words, explain the operation of a capillary tube. _____

Read the following paragraphs from the "Modern Refrigeration and Air Conditioning" textbook and answer the questions.

Read paragraph 4-18.

○ What is the advantage of using a capillary tube that is longer and larger in diameter? _____

Read paragraph 5-26.

○ The design of a capillary tube depends on the following four variables. _____

○ What kind of a motor control must be used with a capillary tube? _____

○ A capillary tube acts as a constant _____ on the refrigerant.

○ What is the purpose of the filter-drier at the inlet of the capillary tube? _____

- ° What is an indication of an overcharge in a capillary tube system?

- ° What are the advantages of a capillary tube system?

Read the following and answer the questions.

2. Metering Orifices

Special metering devices are usually designed by a specific company for their own equipment, and they may not be able to be interchanged with other brands of equipment.

One of the most popular types is known as an accurater.

There are two types of accuraters, a stationary type and a bypass type. These are most common in heat pumps and some air conditioning applications. These have most of the advantages of the capillary tube without the danger of the tube breaking. The accurater is located in the liquid line and it normally looks like a flare fitting with a small metering orifice in the center.

- ° What are the two types of accuraters?

_____ and _____

- ° Where is the accurater located?

- ° What are accuraters normally used on?

- ° Describe what the accuraters look like.

3. Automatic Expansion Valves (AEV)

Automatic Expansion Valves are commonly referred to as constant pressure valves due to the fact that they are designed to maintain a constant evaporator pressure while the unit is operating. One of the advantages is that the valve closes on the OFF cycle. This valve is used on systems that have a fairly constant heat load.

Read the following paragraphs in the "Modern Refrigeration and Air Conditioning" textbook and answer the questions.

Read paragraph 3-7.

- ° When does liquid refrigerant flow through the automatic expansion valve?

- ° What stops this system when the proper temperature in the refrigerated space is obtained?

- ° What would be wrong with the automatic expansion valve if the suction line frosted when the unit was started?
-
-

Read paragraph 4-19.

- ° What controls the rate of flow through an automatic expansion valve?
-
-

- ° What will be the results of turning the adjusting screw clockwise on an automatic expansion valve?
-
-

- ° How does the amount of refrigerant in the system effect the operation of the automatic expansion valve?
-
-

- ° Explain in your own words how an automatic expansion valve controls the refrigerant flow.
-
-

B. Temperature Operated Refrigerant Controls

1. Thermostatic Expansion Valves (TEV)

The TEV is a metering device that is truly fully automatic. It has all the desired operating qualities required to make the evaporator functional. It maintains a fully active evaporator under all heat load conditions by striving to maintain a constant degree of superheat. The power element insures that the valve opens and closes, metering the correct amount of liquid refrigerant to the evaporator as the heat load changes. The power element is actually sensing the superheat and responds to its changes in temperature. The TEVEE is a TEV that is designed to operate on large evaporator systems that have excessive pressure drops across them. This valve senses the evaporator outlet pressure and automatically corrects itself for the pressure drop on the evaporator. This causes more refrigerant to flow through the valve to compensate for the pressure drop. Without the external equalizer, the valve would operate the system in a starved condition.

To troubleshoot a TEV or TEVEE, system suction pressure (heat load) and superheat are calculated. Adjusting the valve is the last thing one should do as malfunctions are rarely caused by the valve being out of adjustment. The TEVs are found on most applications of mechanical-type refrigeration due to its reliability and operation.

- ° What insures that a TEV opens and closes? _____
-
- ° What is the purpose of the TEV? _____
-
- ° What is a thermostatic expansion valve externally equalized (TEVEE)?
-

Read the following paragraphs in the "Modern Refrigeration and Air Conditioning" textbook and answer the questions.

Read paragraph 3-8.

- ° What controls the operation of a TEV? _____
- ° What governs the amount a TEV will open? _____
- ° What happens in the system when the evaporator reaches the desired temperature? _____

Read paragraph 4-20.

- ° Where is the TEV sensing bulb located? _____
- ° What happens as the evaporator becomes colder? _____
- ° Where is the TEV located in the system? _____

Read paragraph 5-10

- ° Superheat refers to the difference in temperature between the _____ and the _____.
- ° What is the result of increasing superheat?
A tendency to _____

C. Special Metering Devices

Other types of special metering devices are known as high side and low side floats. These are used on flooded evaporator systems and are used with centrifugal compression systems.

Read the following paragraphs in the "Modern Refrigeration and Air Conditioning" textbook and answer the questions.

Read paragraphs 5-24 and 5-25.

- ° What is the purpose of a low side float? _____
- ° What is the possible disadvantage of the low side float? _____
- ° With a high side float where is the liquid refrigerant stored? _____

Homework to prepare for day 21.

Read the following paragraphs from the "Modern Refrigeration and Air Conditioning" textbook. Be prepared to discuss and answer questions in class.

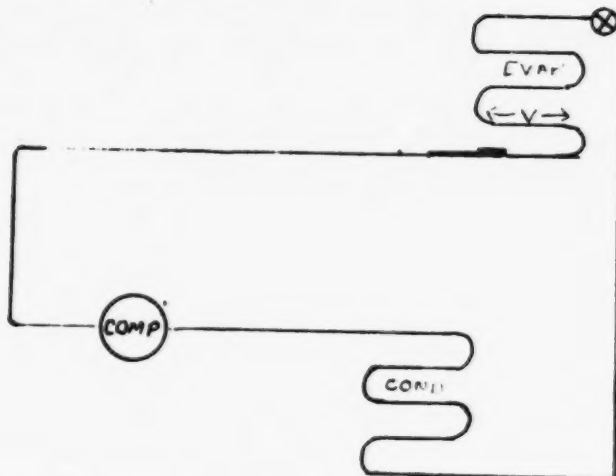
Read paragraphs 5-1 through 5-18, 5-21 through 5-23, 11-51 through 11-53, and 11-63.

STOP! YOU HAVE COMPLETED THE ASSIGNMENT IN PREPARATION FOR DAY 21.

DIRECTED STUDY AND HOMEWORK

Assignment in preparation for Day 22.

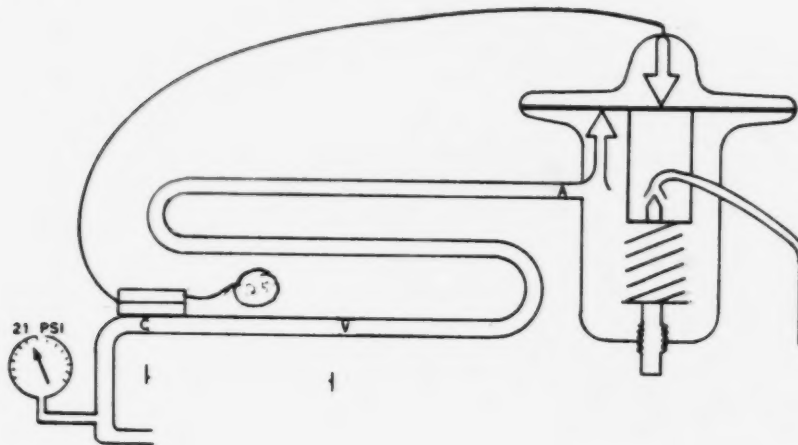
1. Using the system below and P.T. chart along with notes, answer questions below.



- a. The AEV is designed to maintain a constant _____ under all load conditions.
- b. "V" point is where the last drop of liquid refrigerant boils off. Which direction will the "V" point move on an increase of heat load? _____
Decrease of heat load? _____
- c. Determine the AEV setting for the following temperatures. (Remember 10° T.D.)
- | | | | |
|-----|-----|-------|-----|
| (1) | 45° | _____ | PSI |
| (2) | 43° | _____ | PSI |
| (3) | 20° | _____ | PSI |
| (4) | 35° | _____ | PSI |
| (5) | 28° | _____ | PSI |
- d. If the system, using an AEV, cycles OFF on temperature, what does the valve do?

Why? _____

- e. List some examples of the types of systems that an AEV would be good on.



2. Using the diagram above and notes, answer the following questions.

- a. The temperature difference between "V" and "C" point is known as _____

- b. 21 PSI is the pressure at the outlet of the evaporator. What is the temperature at this point? _____
Are the temperatures the same? _____ Why? _____

- c. What would the problem be if the temperature were the same?

Listed below are the necessary steps to remove, replace, and adjust the TEV. Read paragraph 14-63 to aid in answering questions.

Removal

1. Observe all possible safety precautions.
2. Pump down the unit 1-5 psi by cooling king valve.
3. Close evaporator hand valves to isolate evaporator.

4. Remove the old expansion valve using a proper backup wrench to prevent twisting of the tubing.
5. Loosen sensing bulb clamp on outlet of evaporator and remove bulb.

Questions

1. When you pump down a system, what valve must be closed? _____

2. What is the purpose of closing the evaporator hand valves? _____

3. Why must you use a backup wrench when removing an expansion valve?

Replacement and Installation

Read paragraph 14-66 and answer the following questions.

NOTE: Sensing bulbs are installed with a metal clamp using the following rules:
Lines under 7/8" - 12:00 position
Lines 7/8" to 2 1/8" - 4:00 or 8:00
Lines 2 1/8" and up - in a well
Vertical position have the capillary tube facing up.
Evacuate open lines.

Questions

1. After the expansion valve is mounted, what lines are evacuated?

2. On multiple systems, dry evaporators using expansion valves should have what accessories installed in liquid and suction line? _____

Why? _____

3. After installing a TEV with a flare fitting, what must be done to the fitting itself?

Why? _____

4. Any place that 'frosting' occurs, what kind of flare nuts should you use?

5. What is the best type of connection in the interior cabinet in a refrigeration system?

6. What are the proper positions of a sensing bulb on a horizontal suction line for the given diameters?

- a. $3/8$ " _____
b. $2\ 1/4$ " _____
c. $1\ 5/8$ " _____
d. $7/8$ " _____
e. 6" _____

7. Where is the proper sensing bulb location on a vertical run suction line?

STOP! YOU HAVE COMPLETED THE DIRECTED STUDY TO BE COMPLETED PRIOR TO DAY 22.

MOTOR CONTROLS

Assignment in Preparation for Day 23

Adjustment and Calibration of Motor and Safety Controls

A. Using the "Dictionary of Technical Terms" in chapter 30 in the "Modern Refrigeration and Air Conditioning" textbook, define the following terms.

1. Cut-in (CI) _____

2. Cut-out (CO) _____

3. Differential (D) _____

4. Average Temperature (AT) _____

B. Read paragraph 12-38 in the "Modern Refrigeration and Air Conditioning" textbook and answer the following questions.

1. The cut-out pressure should be set about how many degrees lower than the desired evaporator outside surface temperature?

2. The cut-in pressure should be about the same as what allowable evaporator temperature.

3. What is the common pressure difference between cut-in and cut-out point on a R12 system?

C. Read the following paragraph and paragraph 12-40 in the "Modern Refrigeration and Air Conditioning" textbook and answer the following questions.

Sometimes motor controls are used to protect refrigeration systems (primarily the compressor motor) from operating under hazardous conditions. One of these safety controls is the High Pressure Safety Switch (HPSSW). The contacts of this control are set to operate 20% above Normal Operating Pressure (NOP). Normal operating pressure for a HPSSW can be determined by adding the summer design temperature (sometimes called average hot season temperature) to the condensing factor. A rule of thumb for determining condensing factors are as follows: Natural Convection Air Cooled = 35°F, Forced Convection Air Cooled = 30°F, and Water Cooled = 25°F. Using a pressure temperature chart, convert the total of these temperatures to pressure for the refrigerant used in the system. To compute pressure settings for a HPSSW, the following formulas may be used:

CI OR NOP = SUMMER DESIGN TEMPERATURE + CONDENSING FACTOR CONVERTED TO PRESSURE

CO = NOP x 1.20 (CO on the HPSSW is 20% above NOP.)

1. Where is the high pressure safety switch connected on a system?

2. What is the purpose of the HPSSW?

3. How is the normal operating pressure for a HPSSW determined?

4. How is the maximum operating pressure for a HPSSW determined?

- D. Read the following paragraphs pertaining to condenser fan controls and answer the following questions.

One of the main problems with outdoor units is keeping the thermostatic expansion valve operating at full capacity during cold weather. Capacity depends on the pressure difference across the valve. If condensing pressure reduces from 102 PSI, 90F (32C) for R12 to 56 PSI, 30F (-2C) for R12, the valve capacity will drop. (Not enough liquid refrigerant will flow.) The refrigerated fixture temperatures may then rise too high. Also, a small pressure difference may cause short cycling of the condensing unit.

In order to maintain air cooled condensing pressures at a satisfactory level during low ambient conditions, a condenser fan pressure control is frequently used. The control acts to break the circuit to the condenser fan on a drop in condensing pressure and makes the circuit on a rise in condensing pressure. Since this is the reverse of the action on a normal high pressure control, this is often described as a reverse acting pressure control. The contacts of this control are set to operate 20% below normal operating pressure (NOP). To compute pressure settings for a CFC, the following formulas may be used.

CI OR NOP = SUMMER DESIGN TEMPERATURE + CONDENSING FACTOR CONVERTED TO PRESSURE.

CO = NOP MINUS 20% (CO ON THE CFC IS 20% BELOW NOP).

1. As the condensing pressure drops, what will the valve capacity do?

2. What control is required to keep the condensing pressure at a satisfactory level?

3. As the condensing pressure drops, what is the action of the condenser fan control?

4. On a system with a normal operating pressure of 100 PSI, what is the CFC set to cut-out the condenser fan?

E. Read the following paragraph and answer the following questions.

Anytime a motor or safety control require replacement, there are certain precautions that should be observed. These precautions are as follows:

CAUTION: When installing a motor control, observe the following precautions.

- Avoid sharp bends or kinks in the capillary tube.
- Insure the control is large enough to handle the required electrical load.
- Make sure that the pressure range of the control is capable of handling the type of refrigerant in the system.
- Coil excess capillary to avoid vibration.
- Insure that system is disconnected from power source.

1. What is a precaution that should be observed concerning the pressure range?

2. What is required with the excess capillary tube and why?

F. Read paragraph 14-94 in the "Modern Refrigeration and Air Conditioning" textbook and answer the following questions.

1. What are the four types of motor controls that are used in commercial refrigeration?

a. _____

b. _____

c. _____

d. _____

2. The six (6) common troubles encountered with the motor controls are:

a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

3. How can a pressure control operation be checked?

4. A thermostatic motor control may be checked by utilizing what method?

5. What are the two (2) most common troubles associated with high pressure safety switches?

a. _____

b. _____

6. When will an oil pressure safety switch operate?

STOP! YOU HAVE COMPLETED THE DIRECTED STUDY ASSIGNMENT FOR DAY 23.

TROUBLESHOOTING

Assignment in Preparation for Day 24

Troubleshooting Motor and Safety Controls

Read paragraph 14-94 in the "Modern Refrigeration and Air Conditioning" textbook and answer the following questions.

1. List four types of motor controls that are used in commercial refrigeration.
 - a. _____
 - b. _____
 - c. _____
 - d. _____
2. A motor control with corroded contacts should be repaired by

3. How may corroded contacts be temporarily repaired?

4. A thermostatic motor control (TMC) with a broken mercury bulb or lost sensing bulb charge may be repaired. TRUE/FALSE
5. An out-of-adjustment motor control is usually a result of

6. A pressure control's cut-in and cut-out settings may be checked using what 2 items?

7. What is the most common trouble with high pressure motor controls?

8. List the steps to check a high pressure motor control element.

9. A high pressure motor control is designed to work only under _____ conditions.

10. If a high pressure motor control is short cycling a compressor, what would be the cause?

11. What would cause rapid deterioration of contacts?

STOP: YOU HAVE COMPLETED THE DIRECTED STUDY ASSIGNMENT IN PREPARATION FOR DAY 24.

Assignment in Preparation of Day 25

- A. Read the following paragraph and answer the following questions.

Trouble analysis is an organized process of elimination. The first thing to do is install the manifold gauge assembly and operate the system if possible. While the unit is operating, it will give you time to listen to the user's complaint as well as observe the symptoms of the system. In some cases, it is possible to determine the malfunction immediately, while in other cases, you may have to check several things before determining the exact trouble. A few minutes spent in observation and analysis may save hours of work later.

1. _____ is an organized process of elimination.
2. What are the first things that a service specialist should do to analyze a refrigeration system?

3. It is possible to determine the system's malfunction immediately, by checking one thing.
TRUE/FALSE

- B. Read the following paragraph and answer these questions.

To troubleshoot a TEV or TEVEE, system suction pressure (heat load) and superheat are calculated. Adjusting the valve is the last thing one should do as malfunctions are rarely caused by the valve being out of adjustment. The TEVs are found on most applications of mechanical-type refrigeration due to its reliability and operation.

1. When does the service specialist adjust the TEV or TEVEE, while checking a malfunctioning system?

2. The valve being out of adjustment is usually the problem on a malfunctioning system. TRUE/FALSE

C. Read the following paragraphs and answer these questions.

Trouble analysis is the area of refrigeration that separates the parts changer from the service specialist. To be successful at troubleshooting, the specialist must have a thorough knowledge of refrigeration theory and accurate test equipment. The only way to find out what is wrong, is to know what the correct operation should be.

Refrigeration troubles fall into three major categories: electrical, refrigeration system, and refrigerant controls. Electrical problems consume most of the troubleshooting time. Some of the most common electrical problems are shorts, opens and overloads. Most of the problems that occur under the refrigeration system category are restriction (partial or complete), leaks, odors and low capacity. The best way to determine these problems is by the use of temperature and pressure readings along with a person's six basic senses: sight, smell, touch, hearing, tasting, and most of all, common sense. Since refrigerant controls give very few troubles, they should be the last step in the analysis process. Thermostatic Expansion Valves (TEVs) can be analyzed by using the "two symptom method," suction pressure and superheat.

1. What two (2) things must a service specialist have to be successful at troubleshooting?

2. What must you know to find out what is wrong?

3. What are the three (3) categories of refrigeration troubles?

4. Which category consumes most of the service specialist's time?

5. What are a person's six basic senses?

6. Since refrigerant controls give most of your troubles, they should be the first thing you place. TRUE/FALSE

7. What two (2) readings comprise the "two symptom method of analyzing a TEV?

STOP! YOU HAVE COMPLETED THE DIRECTED STUDY ASSIGNMENT IN PREPARATION FOR DAY 25.

DOMESTIC AND COMMERCIAL REFRIGERATION

Assignment in preparation for Day 26.

A. Read the following paragraphs and answer the questions.

Refrigerant Control

All modern domestic refrigerators use a capillary tube refrigerant control. This type of control is simple, economical, and allows the use of a low starting torque motor. One end of the capillary tube is attached to the bottom of the condenser. You may find a strainer installed between the condenser and capillary tube. The capillary tube is soldered to the suction line to act as a heat exchanger and give the capillary tube added strength, and terminates in an expansion chamber at the top of the evaporator.

PRINCIPLE OF OPERATION OF CAPILLARY TUBE. Liquid refrigerant with a pressure of 120 to 140 PSI and a temperature of 90 to 120°F enters the capillary tube. (Pressures and temperatures are approximations.) As the liquid travels through the capillary tube, its pressure is reduced by the resistance of the tubing. At the same time, its temperature is being reduced by the cold suction line. These two forces continue to act on the liquid refrigerant as it proceeds through the capillary tube. However, the pressure is reduced (comparatively) faster than the temperature. At some point (usually within the last 1/3 of the tube) the pressure of the liquid refrigerant is reduced below its boiling point. Some of the liquid refrigerant "flashes" or boils. The vapor occupies more space than the liquid so the resistance to flow is increased. The temperature of the refrigerant is decreased by both the flashing of the liquid and by the action of the cold suction line. The point where the flashing first occurs to the end of the capillary tube is known as a "vapor lock or bubble point."

All capillary tubes have a vapor lock. The length of the vapor lock depends on a combination of the following factors.

- * Condensing temperature.
- * Condensing pressure.
- * Amount of subcooling of the liquid in the condenser.
- * Temperature of the suction line.
- * Pressure difference between the low and high side.
- * The length and diameter of the capillary tube.

1. What does a domestic refrigerator use for a refrigerant control?

2. Between what two (2) components is the capillary tube installed?

3. What is meant by "vapor lock or bubble point"?

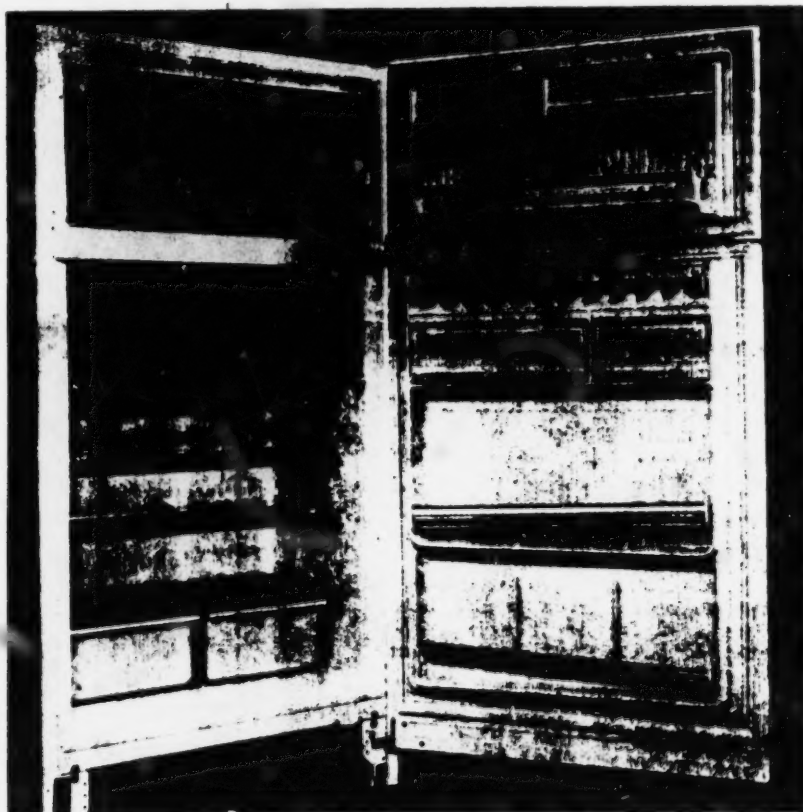
B. Read the following paragraphs and answer the questions.

Since most people are more or less familiar with the common household refrigerator, it will be used in the instruction of hermetically sealed refrigeration units.

DOMESTIC REFRIGERATORS

The term "domestic refrigerators" includes all types of refrigerated boxes normally used in the kitchen. It includes refrigerator-cold storage box combinations, but does not include separate cold storage boxes.

A domestic refrigerator is normally an upright box with one or two doors. It may be either free standing or built into a wall. A modern domestic refrigerator is a self-contained unit as shown below. It can be placed in operation by removing the shipping bolts (if they have them), connecting the power source and adjusting the motor control.



Most domestic refrigerators have at least three different temperature compartments: a freezing compartment for freezing ice cubes and storing frozen foods, a medium temperature area for foods and beverages, and a high temperature, high humidity compartment for fresh vegetables and fruits. They may have such accessories as a butter conditioner, egg shelves, beverage containers, and storage shelves in the door.

1. What does the term "domestic refrigerator" refer to?

2. Most domestic refrigerators have how many temperature compartments, and what are they?

C. Read the following paragraphs and answer the questions.

Construction Features

The outer shell is normally made of several pieces of sheet metal welded together and covered with appliance enamel. The inner shell is usually formed from one piece of metal. It may be either porcelain or enamel finished. The space between the two sheets is filled with insulating material.

INSULATION. Any substance that will retard the flow of heat may be used for insulating purposes. A great number of substances have been used for insulation in domestic boxes. Fiberglas and foamed plastic are the most widely used in domestic refrigerators.

Fiberglas. This is one of the most widely used insulating materials. It is made from silicon dioxide (glass sand) and is expanded with refrigerant or carbon dioxide. When used in domestic refrigerators, it is made in the form of mats and is approximately three inches thick. If it is necessary to handle Fiberglas, wear a long sleeved shirt and rubber gloves as the particles of glass will penetrate the skin and cause a burning, itching condition.

Foamed Plastic. This is a relatively new insulating material. It is manufactured from plastic that has been foamed or expanded by the use of refrigerant, carbon dioxide or some other highly volatile agent. Foamed plastic is more expensive than Fiberglas, but you only have to use half as much of it to get the same insulating effect. Foamed plastic is light in weight, easily worked and may be manufactured in various forms and shapes. Therefore, it makes a very desirable insulating material and is used in the so-called "thin-walled" boxes.

1. What is insulation?
2. What are the most common types of insulating materials used in domestic refrigerators?

D. Read the following paragraphs and answer the questions.

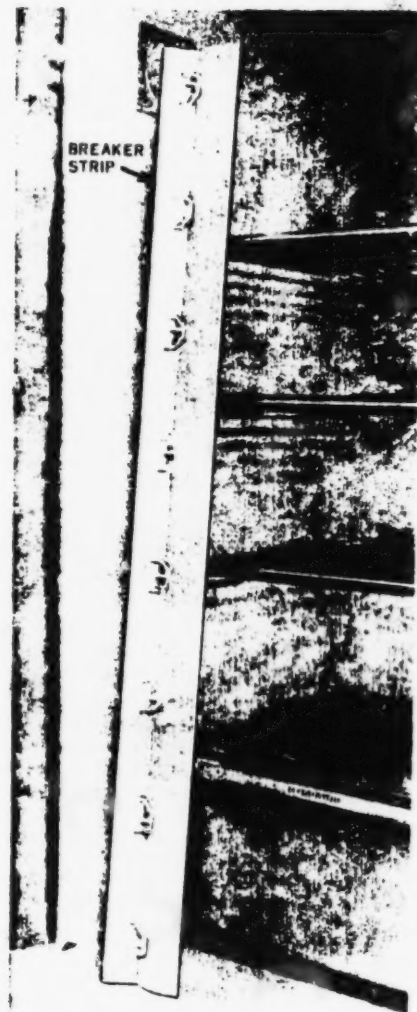
VAPOR BARRIER. Condensation of moisture will occur on any surface that is at a temperature below the dewpoint of the surrounding air. Therefore, we must keep moisture out of the insulated space between the inner and outer shell. This is particularly important around the freezing section. Several substances are used for this purpose, but the most important one in domestic boxes is plastic. The plastic is placed in such a way as to stop the water vapor in the air from getting to the cold surface. The suction line is often insulated with a rubber-like substance known as insulation tape. The holes where the refrigerant or electrical lines go through the box are usually stuffed full of a soft putty-like substance known as permagum cords. An odorless tar is often spread over an area or surface to prevent vapor transmission.

DOOR. The late refrigerator may have either one or two doors. These doors are made to cover the whole front of the refrigerator. The inside of the door may be recessed for small shelves or a butter conditioner. The inside panel is made of plastic. Since the panel is light it aids in reducing the total weight of the door. The plastic panel is designed to aid in keeping the door from warping.

BREAKER STRIPS. The breaker strips are pieces that shield the space between the inner and outer shells. Each manufacturer installs the breaker strips in a different manner. Some use screws, some use clamps, while others snap them in.

Breaker strips are made of plastic. When the strips are cold, they become brittle and will break very easily. Before attempting to remove a cold breaker strip, run a towel dipped in warm water over it. Before installing a cold breaker strip, dip it in warm (not hot) water. This will make it soft and pliable and will reduce the possibility of breakage.

MULLION HEATER. The mullion heater is a strand of high resistance wire attached to a strip of aluminum foil. The mullion heater is installed around the doors under the breaker strips. When the box is plugged in, electricity is applied to the mullion heater which gets warm and adds enough heat to the area around the door to reduce sweating or freezing. A mullion heater is particularly important around the door of the freezer. If the mullion heater fails, moisture will condense around the door and the door will freeze shut.



1. What is used to insulate the suction line?

2. What are the breaker strips made of?

3. What is a mullion heater?

E. Read the following paragraphs and answer the questions.

Major Components

Domestic refrigerators use the same basic components as any other refrigeration system; a compressor, condenser, refrigerant control, and evaporator. However, each of these units are designed for a particular application and temperature range.

COMPRESSOR. Modern domestic refrigerators use a hermetic compressor. These compressors have some outstanding advantages over open type units. In all instances the compressor-motor assembly is much lighter and somewhat stronger as a unit. Strong foundations for mounting the heavy open type compressors are completely eliminated. The faster operating speeds physically reduce the size of the hermetic compressors. The motor and compressor are connected to the same shaft and are positioned as close together as possible. This feature eliminates the bulkiness of the open style system where the motor and compressor were set apart and driven by V-belts.

The most important advantage of the hermetic unit is that the ever troublesome shaft seal is completely eliminated. The elimination of the shaft seal was the prime reason for the development of the hermetic type compressor.

The hermetic design allows the motor and compressor to be enclosed in a housing that is airtight. Moisture, dust, grease, and all foreign particles are sealed out which allows the assembly to operate free of these disturbing elements. As a result the unit functions at full rated capacity for a longer period of time.

Hermetic type compressors operate more quietly than the open style. Any sound originating in the compressor or motor must first pass through the refrigerant vapor within the housing. It must then be transmitted through the steel casing before it can reach the outer area. As a result, the noise is greatly reduced. Vibrations are almost eliminated due to the rapid cycling of the high-speed unit which tends to smooth out larger pulsations. The complete assembly is usually mounted on springs or rubber shock absorbers that dampens out any vibrations that might originate from the assembly.

As a unit, all of the advantages previously discussed indirectly result in an efficiency that places the hermetic unit superior to other types.

Hermetic units have two main disadvantages. They are not easily serviceable in the field and in case of motor burnout the complete system becomes contaminated.

1. What are the basic components of a domestic refrigerator?

2. What are the disadvantages of a hermetic unit?

F. Read the following paragraphs and answer the questions.

Design Characteristics

Reciprocating hermetic compressors have five major design characteristics. These characteristics and some needed information concerning them are listed below.

SHAFT MOUNTING. The crankshaft is mounted either vertically or horizontally.

SHAFT DESIGN. There are three shaft designs: crank, eccentrics, and the scotch yoke. (The scotch yoke is used only on low torque fractional hp compressors.)

METHOD OF LUBRICATION. Hermetic compressors are lubricated by one of the following methods: splash, flood, or forced feed systems.

The splash system is used almost universally in fractional horsepower units. The bearing clearance must be large so that the oil can enter easily. The large bearing clearances aid the splashing effect of the dippers in the oil causing these compressors to produce a little more noise than the other types. The splashing at high speed encourages oil foaming and pumping. The flooded system includes all types of devices that lift the oil up and allows it to flood (run down) over the bearings, pins, and surface areas. The oil is not agitated as violently as with the splash system, which results in quieter operation and less oil pumping. This system is often used in air-conditioning compressors. The forced feed system uses a pump to force the oil through drilled passages to the bearings. The bearings can be closely fitted resulting in very quiet operation. This type system is used on large high-speed compressors.

1. How is the crankshaft mounted?

2. What are the three methods used in lubricating hermetic compressors?

- a. _____
- b. _____
- c. _____

G. Read the following paragraphs and answer the questions.

MOTOR COOLING. The cooler an electric motor operates, the more power it will produce. Therefore, it is imperative that the motor in a hermetic compressor be kept as cool as possible. Hermetic compressors are normally cooled by one or more of the following three methods: suction gas cooling, air cooling, and oil cooling. The suction gas is directed around the motor before it goes to the cylinder. There may be a fan inside the shell that aids in forcing the cold gas around the motor. To prevent oil or liquid refrigerant from entering the suction intake these compressors are designed so that only refrigerant vapor can enter the suction intake due to the fact that suction return vapors must first pass through or around the windings where all the oil and liquid refrigerant will be vaporized. This design is commonly referred to as an antislugging device. Air is used to cool hermetic compressors by both natural and forced convection. Some compressors have external fins that aid in heat transfer. Some domestic refrigerators have a separate oil cooler circuit that cools the oil in the compressor.

SHELL DESIGN. Manufacturers produce hermetic compressors in a variety of shell designs. The mechanics in the field often apply common names to these compressors according to their shape or mounting. These are common names only and may not be familiar to personnel in different geographic areas. The pancake compressor is the only shell design that is accepted industry-wide by both manufacturers and service personnel.

1. What are the three methods used in cooling hermetic compressors?

- a. _____
- b. _____
- c. _____

2. How are the compressors named in the field?

H. Read the following paragraphs and answer the questions.

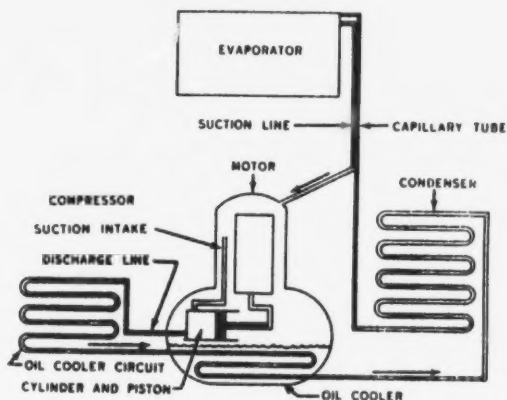
Condensers

The condensers in domestic refrigerators are usually made of steel and are of the following construction types: plate finned (forced convection), coiled tubing with a wire frame, and coiled tubing mounted on the inside of the refrigerator shell. In the last few years, several manufacturers have built the condenser as an integral part of the outside wall. From a visual standpoint, it appears that the unit does not have a condenser. However, let the unit operate for about 30 minutes and then run your hand over the outside of the box. The hot area will indicate the exact location of the condenser. When these units first came out, it was quite difficult to convince some of the users that the outside of their refrigerator was supposed to get hot.

OIL COOLER CIRCUIT

Some compressors used on domestic refrigerators require oil cooling. This is usually accomplished by passing the discharge gas through an oil cooler circuit, desuperheating it, and then returning it to the compressor where it picks up heat from the oil before going on to the condenser.

The schematic below illustrates the hot gas flow through the oil cooler circuit.



Oil Cooler Circuit

Oil Cooler Circuit

1. What is the type of condenser construction used on domestic refrigerators?

2. How is oil cooling accomplished on domestic refrigerators?

I. Read the following paragraphs and answer the questions.

EVAPORATORS

The evaporators used in domestic refrigerators must be rugged, functional, and attractive.

Frosting type refrigerators usually use a flooded type evaporator or a plate with aluminum tubing attached to the back. Very often you will find a refrigerator that uses a plate evaporator with a preformed refrigerant coil in the freezer section. These plate type evaporators are normally made of aluminum. Home freezers often use an evaporator that is composed of coiled aluminum tubing crisscrossed with steel or aluminum wire.

Manufacturers do not recommend attempting to repair aluminum evaporators. When an aluminum evaporator gets a hole in it, the manufacturer recommends replacing the complete assembly.

Suction Line

The suction line is usually attached at the top of the evaporator on domestic boxes. There is usually some surplus section line run along one side or else coiled inside the box. This extra length is to allow the suction gas to pick up enough heat (from the capillary tube) so that the suction line will not sweat outside the box. A sweating suction line usually indicates an overcharge. If the system is correctly charged and the suction line still sweats, it must be insulated to keep the condensate from dripping on the floor. Suction lines are usually made from 5/8 to 3/8 inch copper tubing.

Door Gasket

Domestic refrigerators have a synthetic rubber or flexible plastic gasket around the door. This gasket or seal is designed to make an airtight seal between the door and refrigerator body. Door seals usually last from five to seven years. It is always best to replace door seals with an exact like item. However, this is not always possible. Sometimes you will find it necessary to use a general replacement seal. There are several types of seals in general use. The door should be removed and laid on a flat surface when replacing the gasket. This will prevent warping of the door.

1. What type of evaporator is used on frosting type refrigerators?

2. What does a sweating suction line indicate?

3. What is the purpose of the door gasket?

J. Read the following paragraphs and answer the questions.

During the initial development of the domestic refrigerator, the freezer section was small. It would hold two or three ice cube trays and that was about all. The customer began demanding more and more freezer space until some boxes are one-third freezer space. The freezer must be maintained at about 0°F while the refrigerator section is only 40 to 50°F. Several methods have been employed to maintain these two different temperature ranges within the same box.

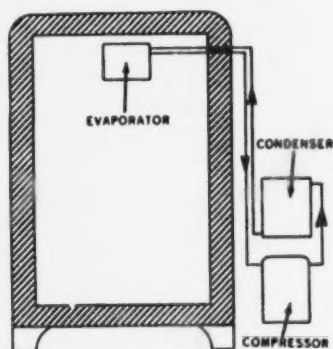
Air Spillover Using One Evaporator

This is the oldest method used to maintain two different temperatures. The cold air that flows (spills over) the frozen food compartment cools the regular refrigerator space. This system has disadvantages. During periods of light usage, the temperatures of the refrigerator space will become too cold. During periods of heavy usage, the refrigerator temperature will be too high even if the temperature of the frozen food area is normal.

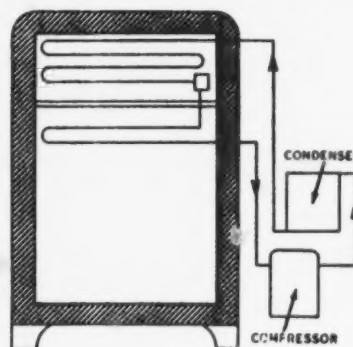
Refrigerant Spillover Using Two Evaporators

In this system the tubing, evaporator size, and refrigerant charge is very critical. The liquid refrigerant goes to the coldest evaporator first. If this area needs refrigeration, all of the liquid is vaporized and the vapor is superheated in the second evaporator before going to the compressor. When the first evaporator is satisfied, the liquid will spill over into the second evaporator and be vaporized there. An accumulator at the end of the coldest evaporator aids in keeping the refrigerant from spilling over too soon.

The compressor is cycled by a thermostat on the warmest evaporator. The evaporator in the fresh food compartment is much smaller than the one in the freezer section. The thermostat cycles the unit off when the saturated vapor reaches the outlet of the medium temperature evaporator.



Air Spillover



Refrigerant Spillover System

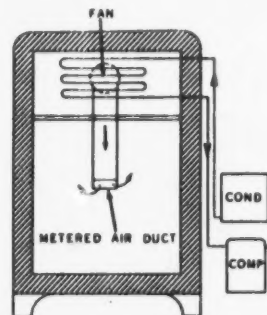
1. At what temperatures should the freezer and the refrigerator section be maintained?

2. On the refrigerant spillover using two evaporator system, what cycles the compressor and what does it sense?

K. Read the following paragraphs and answer the questions.

Metered Chilled Air System

This system is used on modern "no-frost" refrigerators only. It utilizes a finned, forced convection evaporator that is located in the frozen food compartment. A fan forces the air over the evaporator coil and over the food in the frozen food compartment. A critically sized duct runs from the evaporator to the fresh food compartment. Therefore, a metered amount of cold air is forced through this duct into the fresh food compartment. This air is very cold and is usually directed toward the top or sides of the box. If this cold air is allowed to strike a product directly the product will be frozen. Small

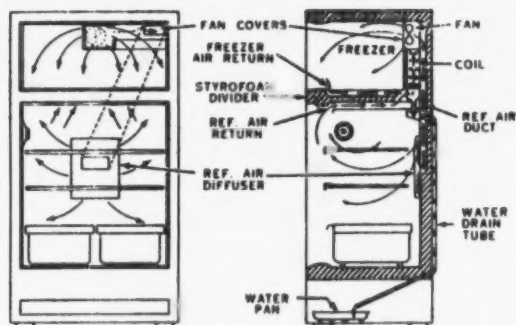


Metered Air System

holes permit the air to return from the fresh food compartment to the freezer compartment. Since the forced convection evaporator is in a low temperature area, it is necessary to use some form of automatic defrost.

Since the thermal bulb or the thermostat is not attached to the evaporator, it feels air temperature only. Most manufacturers place the thermal bulb in the freezer compartment; however, some place it in the fresh food compartment.

AIRFLOW. The freezer air is drawn into the return air duct at the front of the freezer. It passes to the rear between the divider and freezer bottom. It is then drawn upward through the evaporator and discharged into the freezer section.



Airflow in a No-Frost Refrigerator

The sensing element of the cold control is located at the rear of the freezer air return duct, in the refrigerator section the refrigerator air is drawn into the refrigerator air return duct at the top front of the refrigerator section. It passes to the rear of the section between the styrofoam divider and the top of the refrigerator section. It is drawn upward through the cooling coil and discharged into the fan cover by the fan. Part of the air that is discharged into the fan cover is directed into the refrigerator air duct, which is mounted on the insulation side of the liner. The air then passes down the duct and enters the refrigerator section. The amount of air entering the refrigerator is carefully balanced with the amount of air entering the freezer to achieve proper temperatures in both sections.

Today modern refrigerators use variations of the refrigerant spillover and metered air systems on their frost free refrigerators. The evaporators can be located anywhere such as in the lower portion or either side. The refrigerator operates basically the same as those previously listed. The side-by-side refrigerators tend to be larger in size, 20 to 30 cubic feet.

1. What type of refrigerator uses the metered chilled air system?

2. Where is the sensing element of the cold control located?

L. Read the following paragraphs and answer the question.

Domestic Freezers. Domestic freezers were first developed for the storage of frozen foods in the home. These boxes may be either the chest or upright type. The chest type operates more economically and the temperature fluctuations are not as great as with the upright. The upright type box was developed so that a large box would not take up too much floor space. The greatest disadvantage of the upright box is that each time the door is opened, the cold air spills out and is replaced with warm air. This not only causes the unit to operate longer but also causes a large temperature fluctuation within the box.

These freezers are similar in design and operation to that of the domestic refrigerator, except for the lower temperatures that they maintain.

1. What is the greatest disadvantage of an upright freezer?

M. Read the following paragraphs and answer the questions.

Defrost Systems

All modern domestic refrigerators have some type of automatic defrost. Two types of automatic defrost in general use are: hot gas and electrical. In general, all defrost systems have the following major components.

DEFROST TIMER. This is an electrical clock that energizes the defrost systems. There are two different methods of operating the clock timer. (1) Clock timing. This is the simplest and most common method used. An electric clock is wired to the plug-in cord. Any time the unit is plugged in, the clock is running. Some of these timers are set to defrost once every 12 hours, while others defrost every 6 to 8 hours. (2) Running time. The electrical clock is connected to the compressor circuit. Therefore, the clock runs only when the compressor is operating. After a given number of hours of operation, usually about 4 to 8, the timer energizes the defrost system.

DRAIN TROUGH. This unit is located below the evaporator to catch the defrost water as it drops off the evaporator.

DRAIN TROUGH HEATER. An electrical heater located below the drain trough to keep the water from freezing before it has a chance to flow out the drain line.

DRAIN LINE. A piece of rubber or plastic tubing runs from the drain trough down to the drain pan below the refrigerator. If the drain line passes through the freezer area, it must be heated.

DRAIN PAN. A shallow plastic or metal pan located beneath the refrigerator. The defrost water from the evaporator collects in this pan and is evaporated by the heat of the compressor, oil cooler circuit, or condenser.

HEATING MECHANISM. For satisfactory operation, particularly in the freezer section, the time it takes to defrost the evaporator must be held to a minimum. This is accomplished by rapidly heating the evaporator with the hot condenser gas or an electrical heating coil.

DEFROST THERMOSTAT. This unit has several different names: defrost thermostat, termination thermostat, defrost limit switch, and safety control. Regardless of what these units are called, they all work in the same manner and have the same functions.

The unit is a small circular (about the size of a quarter and 1/4 to 3/8 inch thick) plastic or bakelite disc with two wires attached. It is located on and attached to the evaporator. The internal mechanism consists of a bimetal element that is open at 50°F and is closed at 20°F. It has two purposes:

- ° Keeps the defrost heater from getting hot unless the evaporator is cold.
- ° Stops or terminates the defrost cycle when the evaporator reaches 47°F to 50°F.

1. Name the two types of defrost systems used in domestic refrigerators.

a. _____

b. _____

2. Name the two different methods used to operate the clock timer.

a. _____

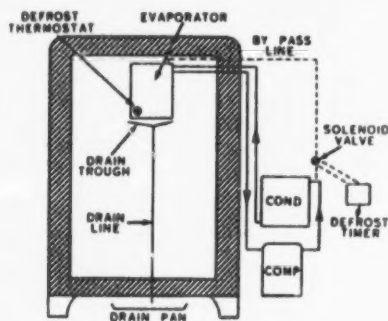
3. At what temperature range is the defrost cycle terminated?

N. Read the following paragraphs and answer the questions.

HOT GAS DEFROST SYSTEM. Figure below illustrates a typical hot gas defrost system. The defrost timer opens the solenoid valve allowing the hot condenser gas to flow through the bypass (dashed line) into the evaporator. The hot gas gives up its heat and melts down the drain line to the drain pan. The heat from the condenser evaporates the water. The drain trough heater keeps the water from freezing before it flows out the drain line.

Some of the hot gas condenses in the evaporator. To eliminate a liquid lock in the compressor, the liquid refrigerant is vaporized by an electrical heating element on the suction line.

Advantages. (1) Cheap operation - by using the heat in the hot gas, the requirement for electrical power is reduced. (2) Fast operation - the hot gas is in direct contact with the tubes in the evaporator. Therefore, the ice is melted very rapidly.



Defrost System

Disadvantages. The hot gas defrost system is more difficult to troubleshoot than the electrical. If the box is located in a low ambient temperature area, there will not be enough heat in the hot gas to completely defrost the evaporator. The ice will continue to build up on the evaporator until it must be defrosted by hand.

1. List and explain the two advantages of the hot gas defrost system.

2. List and explain the two disadvantages of the hot gas defrost system.

O. Read the following paragraphs and answer the questions.

SERVICE AND MAINTENANCE. Hot gas defrost systems are subject to the following three malfunctions or troubles.

* **Solenoid Valve Stuck Open.** The symptoms are: compressor operates all the time, box temperature high, low side pressure high, high side pressure low, and by-pass line warm. Checking procedures for these symptoms are: operate the system and tap the valve with a rubber hammer. If tapping causes the valve to close, it indicates the valve is faulty and should be replaced. If the valve does not close, unplug the unit and disconnect the electrical wires at the solenoid valve. Operate the unit. If the valve closes, the trouble is in the defrost timer. If the valve does not close, replace the valve.

* Solenoid Valve Stuck Closed. The symptom is: The system will not defrost. The checking procedures are: unplug the unit and disconnect the electrical wiring at the solenoid valve. Connect an external power source to the solenoid. Operate the unit. If the solenoid valve opens, the trouble is in the defrost timer. If the valve does not open, the valve must be replaced.

* Solenoid Valve Leaking. The symptoms are: the low side pressure is high, the high side pressure is low and there is a high box temperature. Compressor runs all the time and the bypass line is warm. The checking procedures are: the first four could be caused by a bad compressor. The last symptom indicates that the trouble is in the solenoid valve and not the compressor.

1. List three malfunctions of a hot gas defrost system.

- a. _____
- b. _____
- c. _____

2. List the symptoms of each of the malfunctions listed in question 1.

- a. _____
- b. _____
- c. _____

P. Read the following paragraphs and answer the questions.

ELECTRICAL DEFROST SYSTEM. This defrost system is very simple. It consists of an electrical heating element wound around and attached to the evaporator. The defrost timer turns the compressor off and turns the defrost system on. Electricity flows through the heating element and heats it up. The heat melts the ice on the evaporator. As soon as the evaporator reaches 50°F, the defrost thermostat turns the defrost system off.

Advantages. Complete or positive defrosting of the evaporator; system is simple and easy to troubleshoot.

Disadvantage. The cost of operation.

SERVICE AND MAINTENANCE. Electrical defrost systems are subjected to the following malfunctions or troubles.

* Unit will not defrost. The symptoms are, with the unit operating: box temperature high, very little air coming through the evaporator, and the evaporator covered with frost. Checking procedures are: unplug the unit, defrost the evaporator, and disconnect the electrical wiring at the element. If the heating element gets hot, it is satisfactory, and the trouble is in the timer. If the heating element does not get hot, it is faulty and must be replaced.

* Unit on defrost and will not change back to normal operation. The symptoms are: box temperature high, evaporator completely defrosted, compressor hot operating, and the defrost heating element is hot. Checking procedures: the first three symptoms could be caused by several different conditions. The fourth symptom indicates that the trouble is in the defrost timer.

* Unit will not defrost completely. The symptoms are: unit has a long on-cycle, box temperature high, small amount of air coming through the evaporator, and part of the evaporator covered with frost. Checking procedures: the symptoms, particularly the fourth one, indicate that the defrost thermostat is stopping the defrost cycle too soon. Replace the defrost thermostat.

1. List two advantages of the electrical defrost system.

- _____
- _____

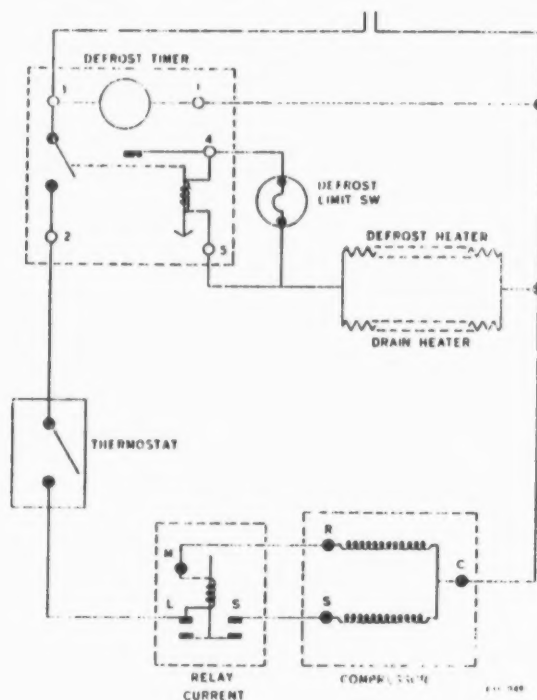
2. List one disadvantage of the electrical defrost system.

3. List and explain three malfunctions of electrical defrost systems.

Q. Read the following paragraphs and answer the question.

DEFROST SYSTEM WIRING DIAGRAM. There are several types of defrost timers used on domestic refrigerators. The defrost timer is illustrated below. This timer consists of four major components. They are as follows: an electric motor that runs continuously, a rotor (with a lobe) that provides two sets of defrost cycles for each rotation, a reset solenoid, and two sets of contact points, one set is always open when the other set is closed. During normal operation, as shown below, electrical current is supplied to the compressor through the closed contact points 2 and 3. When the rotor moves far enough, movable contactor 3 moves up to the lobe and opens contact points 2 and 3 and closes contact points 3 and 4. Current is now supplied to both the defrost and drain heaters. When the evaporator warms up to 50°F, the defrost thermostat (defrost limit switch) opens and stops (terminates) the defrost cycle by energizing the reset solenoid, which opens terminals 3 and 4 and closes 3 and 2 to start the compressor. When the evaporator temperature drops to 20°F the defrost thermostat resets closed, ready for the next defrost.

The wiring diagram below is for the electrical defrost system. This same type of timer can also be used with hot gas defrost systems by substituting a solenoid valve for the defrost timer.



Defrost Timer

1. Name the four major components of a defrost timer.

- a. _____
- b. _____
- c. _____
- d. _____

STOP! YOU HAVE COMPLETED THE DIRECTED STUDY IN PREPARATION FOR DAY 26.

Assignment in preparation for Day 27.

Charging and Evacuating a Capillary Tube System

It is sometimes difficult to determine when a system is correctly charged. No one method will work in all applications. Each system, the units in it, its temperature range, and application, must be considered. The following guidelines will help you, but experience and trial and error are necessary before you become competent in determining the correct charge in a refrigeration system.

A. Read the following paragraph and answer the question.

One method of determining a correct charge is to use a portable charging station. A charging station is a charging cylinder mounted on a portable handcart, complete with a manifold gauge assembly and a vacuum pump. This is illustrated in figure 14-92 in the "Modern Refrigeration and Air Conditioning" textbook. The main advantage of using this type of unit is that it is fast. A given amount of refrigerant can be put in the system in a relatively short time. It removes the guesswork. If you know exactly how much refrigerant a unit requires, this amount is automatically placed in the system. The ease of operation makes this system quite valuable, because it permits inexperienced personnel to be used. A qualified service mechanic does not have to be available when using this charging station, as long as the operator observes details carefully.

1. What are the advantages of charging with a charging station?

B. Read the following paragraph and answer the questions.

Another manufacturer makes a device called a "chargefaster" which connects directly to the compound side of your manifold assembly. The compound hose connects to the "chargefaster." It is a calibrated restrictor device designed to convert liquid refrigerant into a vapor. As the liquid refrigerant passes through the device it is converted into a saturated vapor at a rate below the capacity of the compressor, thus eliminating the danger of liquid slugging to the compressor. When charging a unit with the "chargefaster," the saturated vapor enters the suction line and frost will form on the line or service valve. This initial frost remains while charging. When the frost has completely disappeared, shut off the refrigerant supply as the unit is properly charged. When charging refrigerators or freezers use the "chargefaster" in conjunction with a calibrated charging tube for accuracy, speed, and to maintain the pressure within the charging tube for the duration of the charging procedure.

"Chargefaster" is a trademark and the name is used herein to give the operation only. Other manufacturers may have other designs to accomplish the same idea, using another name and method.

1. Where is a "chargefaster" connected?

2. As the liquid refrigerant passes through the "chargefaster," what occurs to the refrigerant?
-
-

3. When charging a unit with a "chargefaster," when the frost has completely disappeared, what does it indicate?
-

C. Read the following paragraph and answer the questions.

In systems that use accumulator spaces at the outlet of the evaporator, one must be careful of the amount of refrigerant charged into these systems. A common method is to slowly charge these systems with refrigerant in the vapor state until the suction line starts to sweat and/or frost back at the evaporator outlet. Then purge a little at a time until the "frost back" disappears. This method is commonly known as the "Direct Method."

1. When charging a unit using the Direct Method, what state is the refrigerant in as it enters the suction line?
-

2. Explain the procedures of charging a unit using the direct method.
-
-

D. Read the following paragraphs and answer the questions.

EVACUATION. Newly installed systems and existing systems that have become contaminated with moisture, dirt, or foreign gases must be evacuated before they will perform properly. In existing systems, the refrigerant's characteristics will change, and it cannot meet the necessary temperatures and pressures for efficient cooling. When this happens, we must evacuate the system with a vacuum pump.

Under normal atmospheric pressures, water boils at 212°F., but if the pressure is reduced to about 2.2 inches Hg it will boil and vaporize at about 100°F. If the pressure is further reduced the moisture will vaporize at even lower temperatures. We need a high vacuum (or a deep vacuum pump) to evacuate the system low enough to remove as much of the contaminants as mechanically possible. Using an ordinary compressor as a vacuum pump, we can only pull enough vacuum to rid a system of water. The two most common vacuum pumps in the field today are the single-stage and the two-stage. The single-stage pump is normally used with the triple method of evacuation, and the two-stage pump is used to evacuate by the deep vacuum method. Pumps are rated on two characteristics: the blank-off pressure, or the vacuum level the pump can achieve, and the speed with which it can pump the system down. There are two designs of pumps - the piston (or vapor) pump and the vane (or rotary) pump. The rotary-type pump is by far the more efficient.

The rotary type consists of a cylinder with an inclosed, eccentric disk. Movable vanes run through the disk and seat against the cylinder. These vanes create suction as they move past the intake valve, thus exhausting the gas. The better rotary pumps are two-stage, or two rotary units in series. The first stage takes the air from the low pressure of the refrigeration system and exhausts it to a higher pressure environment. The second stage sucks in the exhaust gas and exhausts it into the atmosphere. Much lower vacuums can be pulled with a two-stage pump over a single-stage.

1. Why are vacuum pumps needed for a refrigeration system?
-
-

2. What are the types of vacuum pumps? Which is the most efficient?

3. How does it work?

E. Read the following paragraphs and answer the question.

During the evacuation procedure the water vapor and the pump oil come in contact with each other. The oil will absorb the water vapor until the vapor pressure of the water in the oil is so high that the pump cannot maintain a high vacuum. The oil in small vacuum pumps should be changed after approximately 10 hours of operation. Oil that contains a large amount of absorbed moisture loses its lubricating properties. A large number of vacuum pumps are damaged each year because of the oil not being changed often enough.

When you evacuate a large system or use the vacuum pump in the shop under continuous conditions, a cold trap between the refrigeration system and the vacuum pump will keep the water vapor from contacting the pump oil. As the moisture vapor contacts the cold service, it will turn to ice. We then simply close valves on both sides of the trap, unbolting it, and remove the ice.

1. What causes the most damage to vacuum pumps?

Homework in preparation for Day 27.

Read the following paragraphs from the "Modern Refrigeration and Air Conditioning" textbook. Be prepared to discuss material and answer questions in classroom on the assigned material.

Paragraphs 9-35, 11-37, 11-45, 11-46, 11-75, 11-76, 11-77, 14-10, 14-12, 14-30 and 14-32.

STOP! YOU HAVE COMPLETED THE ASSIGNMENTS IN PREPARATION FOR DAY 27.

HERMETIC AND SEMI-HERMETIC COMPRESSOR SYSTEMS

Directed Study Assignment in preparation for Day 28.

TERMINAL IDENTIFICATION

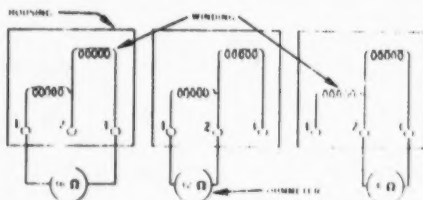
A. Read the following paragraphs and complete the exercise.

When using special test equipment to troubleshoot electrical malfunctions of hermetic and semi-hermetic compressors, the service technician must be able to identify the common, run, and start terminals. This is required for correct hook-up of various pieces of equipment.

There is a possibility that they may be marked or that the technician can identify by use of the schematic. When the terminals are not identified, it is possible to determine proper identification in the following manner.

Terminal Identification

1. The first step is to number the terminals, start from TOP to BOTTOM, or LEFT to RIGHT, depending on your terminal lay-out with 1, 2 and 3.
2. The second step is to measure the resistance (using R X 1) with three combinations of numbers:
 - a. 1 to 2
 - b. 1 to 3
 - c. 2 to 3
3. The highest reading obtained will indicate the start and run windings because it is a measure of the resistance in both windings. This will immediately identify the other terminal as being the common. The next higher reading will identify the start and the lower reading will identify the run terminal.
4. Using the figure below, and the ohm readings listed, letter the terminals as Run, Start, and Common.



Taking Readings Across Terminals

NOTE: The highest reading obtained was between terminals 1 and 3, so we can say that these terminals are the start and run terminals. This means that terminal 2 has to be the common terminal. To determine which is the start and run terminals, observe the readings from the common terminal (terminal 2) to each of the other terminals. The highest of these two readings indicates terminal 1 is the start and the lower reading to terminal 3 indicates it is the run terminal.

5. a. Terminal Readings:

1 and 3 = _____

1 and 2 = _____

2 and 3 = _____

b. Terminal Identification:

1 = _____

2 = _____

3 = _____

NOTE: This identification will also determine the motor winding conditions. The two lower readings obtained (12 and 14) should equal the larger reading (16). If they don't, it means the windings are cross-shortened and the compressor motor is no good.

6. Using the terminals shown to the right and the ohm values to the left, letter the terminals as Run, Start and Common. Also draw in the motor windings as they should be arranged to the terminal letters.

a. 1 to 2 = 11 Ohms

1 to 3 = 4 Ohms

2 to 3 = 15 Ohms

b. 1 to 2 = 14 Ohms

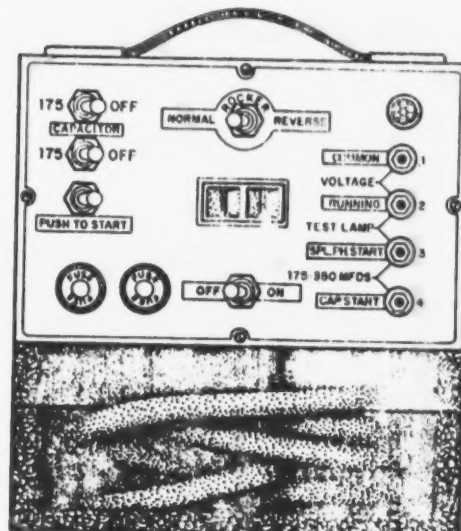
1 to 3 = 6 Ohms

2 to 3 = 8 Ohms

B. Read the following paragraphs on the motor start-analyzer and answer these questions.

The motor start-analyzer can be used for servicing hermetic compressor motors by checking the continuity of the winding and checking for grounded windings. It also has the capability for momentarily reversing the rotation of the compressor motor to free a unit that is stuck for some internal reason. The analyzer may also be used to start split-phase and capacitor start motors; however, you must remember when you are starting the unit with the analyzer you are bypassing the starting relay, and when starting capacitor start motors you must use the capacitor in the analyzer.

CAUTION: Do not use the analyzer to reverse a motor compressor unless the compressor is stuck and then the rocking operation should not exceed five times in 15 seconds.



Motor Start Analyzer

1. The motor start analyzer may be used to accomplish what 2 motor winding checks?

2. Why would the service specialist want to reverse the rotation of the compressor?

3. When using the motor start analyzer to start a compressor, you will bypass what electrical component?

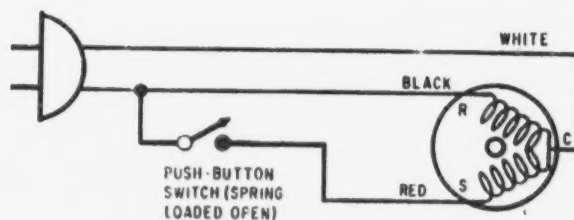
4. How long may the rocking operation, to unstick the compressor, continue?

C. Read the following paragraph on the Pushbutton Starter Cord (Jump Cord) and answer the questions.

If the motor does not start after checking the motor circuit and motor control, the trouble may be in the starting relay. The pushbutton starter cord can be used to bypass the relay and start the motor. These starter cords come equipped with a normal plug-in on one end and three alligator clips on the other end. The pushbutton switch is

spring-loaded to the open position. The alligator clips are color-coded as follows: White-Common. Black-Run, and Red-Start.

CAUTION: The start button must not be held down more than a few seconds. If the compressor starts, the starting relay is faulty and must be replaced.



Schematic Pushbutton Starter Cord

1. What may be the trouble if the motor does not start and you have checked the motor circuit and motor control?

2. What may a service technician use to bypass the starting relay?

3. What is the normal position of the pushbutton switch?

4. What is the color code for the alligator clips?

5. While using the starter cord, the motor starts. What must be done?

STOP! YOU HAVE COMPLETED THE DIRECTED STUDY ASSIGNMENT IN PREPARATION FOR DAY 28.

Directed Study Assignment to be completed prior to Day 29.

Proper operation of starting relay, and checking electrical system for shorts and current flow.

A. Read the following paragraphs and answer the questions.

Starting Relays

Hermetic compressors normally use an induction motor with two windings: a start winding and a run winding. This requires some type of switch to automatically disconnect the start winding as soon as the motor reaches approximately $\frac{3}{4}$ of its rated rpm. The automatic function is performed by a switch known as a starting relay.

Types: 1. Current

- a. Open Coil
- b. Enclosed Coil

2. Time Delay

- a. Hot Wire
- b. Thermal

3. Potential

1. At what rpm is the start winding disconnected from the circuit?

2. Name the 3 types of starting relays.

a. _____

b. _____

c. _____

B. Read the following paragraphs and answer the questions.

Current Relay

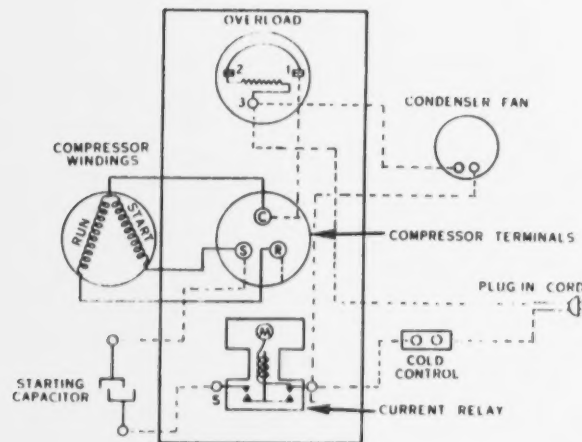
The current relay is used on low torque, fractional horsepower motors.

ADVANTAGES. Smaller and cheaper.

DISADVANTAGES. Points open during high current draw resulting in arcing of its points.

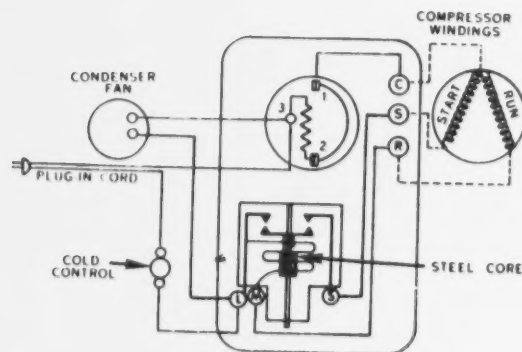
OPERATION. This relay operates on the principle that current draw is highest when the motor is starting than at any other time. The points of the relay are normally open when the compressor is not operating. When the thermostat closes, the current rushes in and magnetizes the relay coil. This causes the relay points to close. After the motor reaches two-thirds to three-fourths of its rated rpm, the current flow will drop and the magnetic field around the relay coil will decrease. The points will then be opened by gravity. Open contacts cut the start windings out of the circuit. The run winding takes over. The current relays have three terminals usually identified as L, S, and M. This relay can be used with a starting capacitor. If a start capacitor is used, it will be located in the start lead between the compressor and the relay.

— Open Coil Relay (Current). The wiring diagram for this relay is illustrated on next page. The dash lines are electrical wiring connections. The solid lines are internal connections between the compressor terminals and motor windings.



Current Relay (Open Coil)

— Enclosed Coil Relay. An enclosed coil relay is illustrated in figure below. The operation of this relay is the same as the open coil type. However, in this case the coil is not seen. It is enclosed in a housing with the points. If you study both diagrams, you will see that nothing but the compressor wires go through the thermal overload. The thermal overload is sized only for the compressor amperage.



Current Relay (Enclosed Coil)

1. What type of motor is a current relay used on?

2. Name the two types of current relays.

a. _____

b. _____

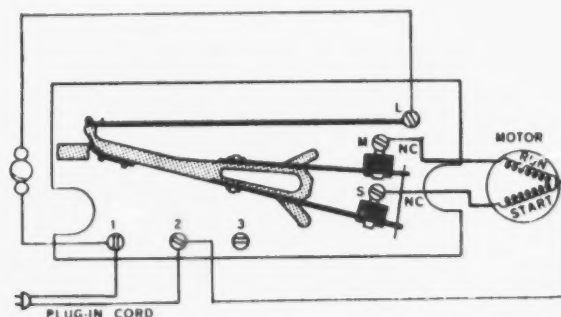
3. Name the disadvantage(s) of the current relay.

C. Read the following paragraphs and answer the questions.

Time Delay Relay

Thermal and hot wire are both used on low torque, fractional horsepower motors. These relays have their own built-in safety device and do not require thermal overloads.

— Hot Wire Relay. This relay operates on the principle that electricity passing through a conductor produces heat, and heat makes metals expand. Figure below illustrates a typical hot wire relay installation.



Hot Wire Relay

The contact points, see figure above, at M and S are normally closed. When the motor control closes, current flows from the line to terminal 1 and up to terminal L. The current flows from the terminal L down the hot wire and through the internal mechanism, to the M and S contact points. From there it flows through both the run and start winding and out the common terminal to the line. At this moment, current is running through both the run and start windings and the motor starts. At startup, there is a large current flow through the hot wire. The hot wire gets hot and expands. This small increase in length allows the internal mechanisms to move enough to open the start contact points. This stops the flow of current through the start windings but the motor continues to operate on the run windings. If the current flow through the run windings becomes excessive,

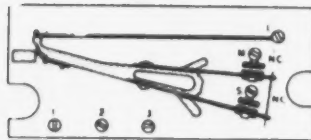
the hot wire will again increase in length and the internal mechanism will move enough to open the M contact points and stop the motor.

It is obvious that the amount the hot wire will expand at a given temperature is very critical.

DISADVANTAGES. The hot wire relay is not as reliable as the current relay because the tension on the wire is affected by ambient temperature. It is difficult to troubleshoot. These units will operate just perfectly as long as you are watching or checking them. However, at the most inopportune time, such as nights, holidays, or weekends, the start contact points will fail to close on the "off" cycle.

Hot wire relays have been used on a great number of domestic refrigerators in the past. However, at the present time most manufacturers are using the current relays which is smaller and less troublesome.

When the box temperature increases and the motor control closes, the compressor will fail to start, because the start contact points are open. The unit continues to warm up and defrost. When the user comes in and opens the door, he finds the box warm and the evaporator defrosted. He calls a serviceman, but the opening and closing of the door has "jarred" the unit enough so that the contact points close. When the serviceman gets there, the unit is operating perfectly. Troubles like these can cause refrigeration servicemen many headaches.



Hot Wire Relay

1. Name the two types of time delay relays.

- a. _____
- b. _____

2. These relays do not require what safety device?

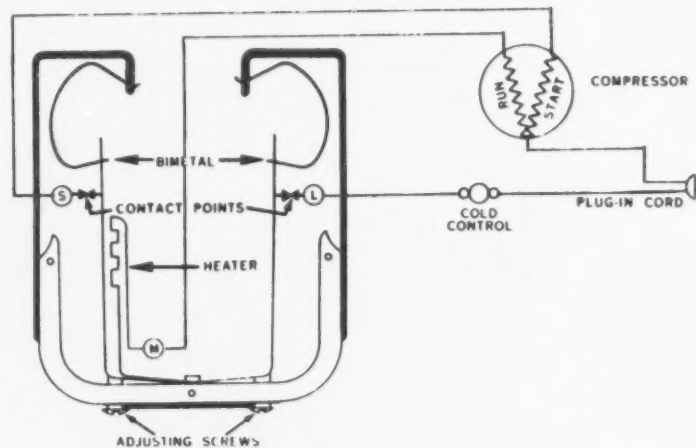
3. Name the three disadvantages of the hot wire relay.

- a. _____
- b. _____
- c. _____

D. Read the following paragraphs and answer the questions.

Thermal Relay (see figure below).

This relay operates on the principle that a bimetallic element will bend when heated. With the cold control open, both contact points are closed, as illustrated in figure below. When the cold control closes, current comes in terminal "L" and goes out both terminals "M" and "S." The compressor is at rest so there is a large current flow through the heater and the left-hand bimetal strip. The bimetal strip gets hot and moves to the right, opening the contact points. The start windings are cut out of the circuit and the compressor continues to operate on the run winding. There is enough current going through the run winding to keep the heater hot enough to keep the bimetal strip from returning to its original position. When the cold control opens, the heater will cool off, and the bimetal strip will return to its original position.



Thermal Relay

The overload protection is provided by the right-hand bimetal strip. During normal operation, the right-hand contact points are closed. High current flow will heat the bimetal strip, and it will move to the left, opening the contact points. As soon as the bimetal strip cools off, it will return to its original position.

1. The thermal relay operates on what principle?

2. How is the overload protection provided?

E. Read the following paragraphs and answer the questions.

Solid State Relay

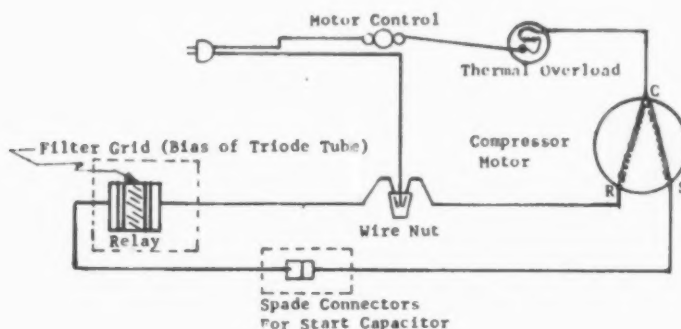
Solid state relays are relatively new just being introduced to the field in the past few years. They are primarily used to replace the current, hot wire and thermal relays which are used on fractional horsepower and low torque motors. It is possible that one relay would fit every refrigerator and most small water coolers on an Air Force base.

The major advantages that the solid state relay has over the other relays are:

a. Cost. Its cost is about one-fourth that of other relays.

b. Reliability. Other relays have a fail-safe factor of ten thousand to fifteen thousand trouble-free starts, whereas the solid state is rated over fifty thousand trouble-free starts.

***** THEY DO NOT USE CONTACTS *****



Solid State Starting Relay

1. When are solid state starting relays used?

2. Name the two advantages of a solid state relay.

a. _____

b. _____

F. Read the following paragraphs and answer the questions.

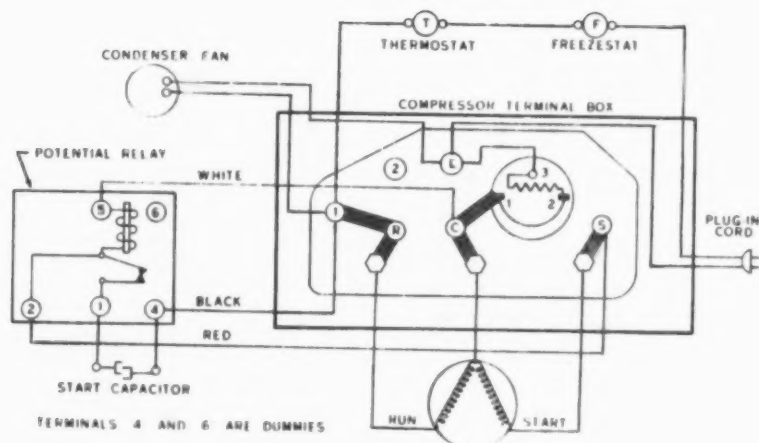
Potential Relay

ADVANTAGES. The points open during low current, thus reducing electrical arcing.

DISADVANTAGES. Potential relays are larger and cost more than the current relays.

APPLICATION. Systems use high-torque motors and automatic or thermostatic expansion valves. This relay is position sensitive to the extent that it must be mounted in the same position as the original factory application.

TYPICAL POTENTIAL RELAY WIRING CIRCUIT. A typical potential relay wiring circuit is illustrated on the next page. This is the wiring diagram of a glass filter type water cooler. After thoroughly studying this circuit, locate and identify each of the major components, terminals and electrical conductors.



Potential Relay

1. Name the advantage of a potential relay.

2. Name the disadvantage of a potential relay.

G. Read the following paragraphs and answer the questions.

OPERATION

The freezestat is for safety purposes only and is normally closed. It only opens if the temperature of the water drops down near 33°F (see figure above). When the thermostat closes, current can flow from the plug-in cord, through the freezestat and thermostat to terminal 1. At this moment three circuits are completed.

Condenser Fan Circuit. Current flows from terminal 1 through the condenser fan motor to terminal L and back to the plug-in cord.

Run Circuit. Current flows from terminal 1 through the conductor strip to terminal R. From terminal R, the current flows through the conductor strip to the compressor terminal. From this point it flows through the run winding (in the compressor), out the common terminal, through the overload, and back to the plug-in cord.

Start Circuit. Current flows from terminal 1 on the compressor terminal box to terminal 4 on the relay. From terminal 4 it flows through the start capacitor to terminal 1. From terminal 1 it flows through the contact points (which are normally closed) to terminal 2. The applied voltage is not strong enough to force current through the small high resistance wire in the coil. Therefore, at this moment there will be no current flow from terminal 1 to terminal 5. Current flows from terminal 2 to terminal S and then through the start windings (in the compressor) to terminal C. From this point it flows through the overload and out to the plug-in cord.

At this moment, the compressor motor starts. As the motor comes up to about two-thirds of its rated rpm, the run winding induces a voltage into the start windings. This induced voltage is high enough to force current to flow from terminal C to terminal 5 and through the coil to terminal 2. From terminal 2 the current flows to terminal S and back to the start winding contact points in the relay. The motor is now operating on the run winding only. The contact points are kept open by the voltage that the run winding induces into the start winding.

1. What is the purpose of the freezestat?

2. Name the three circuits that are completed when the thermostat closes.

a. _____

b. _____

c. _____

Homework in preparation for Day 29

Read the following paragraphs from the "Modern Refrigeration and Air Conditioning" textbook. Be prepared to discuss material and answer questions in classroom on the assigned material.

Paragraphs 6-8, 6-9, 6-11, 6-13, 6-14, 6-19, 6-20 and 6-21.

STOP! YOU HAVE COMPLETED THE ASSIGNMENTS IN PREPARATION FOR DAY 29.

Directed Study Assignment to be Completed Prior to Day 30

Operation and Construction Features of Icemakers

A. Read the following paragraphs and answer the questions.

Ice-Making Machines

Several types of machines are manufactured for making ice cubes or flakes.

Ice-cube makers are classed according to the evaporator as of the (1) tray type, (2) tube type, (3) cell type, or (4) plate type. In comparison, machines for making ice flakes are classed as of the (1) plate type, (2) rotating-cylinder type, and (3) flexible-membrane type. These latter types of machines all have the same purpose, but they employ different types of evaporators.

Components. Whatever the type, the parts ordinarily found in most ice-making machines are a hermetic or semihermetic compressor; a condenser cooled by air, water, or a combination of both; and a receiver-drier-strainer. The refrigerant control can be (1) a capillary tube, (2) an automatic expansion valve, or (3) a thermostatic expansion valve. Of these, a system using a thermostatic expansion valve will require a receiver. Where evaporator heat is used to loosen the ice, you will find a hot-gas solenoid valve. The water-handling system will be continuous-flow or intermittent. Also, the control of the ice-forming and harvest cycle will be on a continuous basis in the rotating-cylinder type, with the starting and stopping of the unit being the main control function. An automatic-tray type will follow a cycle which is timed in the manner which we have already described for an automatic ice-cube maker in a refrigerator.

1. How are icemakers classified?

2. What is required on icemakers using thermostatic expansion valves?

3. Where evaporator heat is required to loosen the ice, you will find a _____

B. Read the following paragraphs and answer the questions.

Ice-Cube Evaporators

The biggest difference found among ice-making machines lies in the evaporator used. Because the tray-type evaporator has already been described, it should give you no difficulty. Since the main difference among such machines lies in the methods of ejecting the cubes from the tray used, we will not discuss it here; tube-type evaporators will be taken up first, instead.

Tube-type Evaporators. In this arrangement, the evaporator is a tube within a tube. Water flows through the inside tube, and refrigerant flows through the outside tube surrounding the inner tube. As more ice is formed, the hole in the center becomes smaller and restricts the flow of water until finally the excess water or water pressure triggers the harvest cycle. A hot-gas solenoid valve operates first, to allow the evaporator to release the ice. In one machine, the long rods are cut into suitable lengths. In another machine, the evaporator tubes are chilled in sections so that rods of the desired length are formed between the warm spots. Still another method uses accumulated water pressure to eject the ice rod with enough force to break it.

Cell-Type Evaporators. There are two major variations of the cell-type evaporator. In one, the cell operates under water, and when the ice is released, it floats to the surface, where it is forced from the tank by a current of water. In the other type, inverted cells are used which have water sprayed against them. The ice-forming period is set by a timer, which then frees the ice by hot gas.

Plate-Type Evaporators. Among the variations of the flat-plate type, there is one main distinction: the plate may be either horizontal or vertical. For instance, in one type of machine, the horizontal plate produces a slab of ice, which is then moved on to a hot-wire grid which is heated electrically. Here the slab melts into individual cubes, which then fall through into a storage bin.

Another such machine uses a grid which is moved into position against a vertical plate. After the cube is formed, the grid is moved against a knockout plate which ejects the cubes. In one design, two vertical plates have matching cold spots which face each other. A unique feature of this model is a variable control over the length of the period for forming ice. Within a short period, the ice produced will be like a lens. If the period is long enough, the two opposite lenses will build a bridge to each other and produce a piece of ice which looks like a yo-yo.

1. What is the biggest difference found in ice-making machines?

2. In the cell-type icemakers, ice-forming period is set by a _____ which then frees the ice by _____.

3. What is one main distinction using plate-type evaporators?

C. Read the following paragraphs and answer the questions.

Flake-Ice Machines

These units use some evaporators which are similar to those of the ice-cube makers, but the harvesting method employed is different.

Plate-Type Evaporator. In this type of evaporator, a thin sheet of ice is formed on the plate. When the desired thickness is reached, hot gas is directed to the plate to loosen the ice, which then passes through a crusher or grinder. Another arrangement freezes the slab in a spring-metal grid. After it is free of the plate, the flexible grid is drawn over a sharp bend, causing the ice to fracture into small pieces. A variation of this last method uses a flexible belt or membrane which passes over a plate or a refrigerated roller. The belt breaks up its cargo by passing around a sharp bend.

Cylinder-Type Evaporator. Again, in this type, there are many variations, but the essential items are a refrigerated cylinder and a cutter-scraper for harvesting. Water may be flowed or sprayed on the cylinder continuously. Harvesting occurs when the ice becomes thick enough to contact the cutters. The machine will continue to make ice until a level is reached in the storage bin, where the ice contacts a feeler which, in turn, will stop the machine. The operation of the feeler is the same as that in the storage bin of an automatic ice-cube maker. The position of the feeler determines the amount of ice which will be stored in the bin before the machine is stopped.

1. Some of the evaporators are similar to those of the ice-cube makers, but the method is different.

2. On the cylinder-type evaporators, when does the harvesting occur?

3. What will cycle (stop and start) a flake-maker ice machine?

4. What determines the amount of ice which will be stored in the storage bin?

D. Read the following paragraph and answer the question.

Troubles in Ice Makers

With so many different types of ice-making machines being used, you will find that it is necessary to have the right service manual for the equipment on hand when you are dealing with mechanical troubles or needed adjustments. You will find, too, that after mechanical problems, the water supply is probably the next greatest source of trouble. Sediment, scale, and salt formation are problems which vary widely from one locality to another. In fact, under severe conditions, water treatment may be the only means of keeping an automatic ice maker in satisfactory operation. On the other hand, in some localities, the domestic water supply contains so much salt that crystals lodge in the seat of a faucet, causing it to drip. Thus, such faucets in everyday use require that incrustation be removed from the stem and gasket every 2 or 3 months.

1. Besides mechanical problems, what is the next greatest source of trouble?

Explain _____

E. Read paragraph 12-25 in the "Modern Refrigeration and Air Conditioning" textbook and answer the questions.

1. The surface of the evaporator is cold (_____), so that the water is _____
2. How is ice formed in a tube-within-a-tube-type icemaker?

Explain _____
3. What is the purpose of a cube-size control?

4. Why is it very important that the drain water be piped to a drain with an air break?

F. Read paragraph 13-17 in the "Modern Refrigeration and Air Conditioning" textbook and answer the questions.

1. What does cloudy ice cubes indicate?

2. What controls the water flow?

3. How often should ice cube makers water circuit and ice freezing parts be cleaned?

G. Read paragraph 14-54 in the "Modern Refrigeration and Air Conditioning" textbook and answer the question.

1. How often should the parts of the ice maker which are in contact with water be cleaned?

STOP! YOU HAVE COMPLETED THE DIRECTED STUDY ASSIGNMENT IN PREPARATION FOR DAY 30.

LARGE COMMERCIAL REFRIGERATION SYSTEMS

Directed Study Assignment to be Completed prior to Day 31.

Construction Features and Operating Principles of Walk-in Boxes and Cold Storage Plants

Read the following paragraphs from the "Modern Refrigeration and Air Conditioning" textbook and answer these questions.

Paragraphs 13-1, 13-3, 12-27 through 12-29, 12-31 through 12-33, 12-44.

1. Cabinet surfaces are either _____ or _____, and finishes are formulated for easy _____.
2. The insulation, in new units, is usually _____ or _____.
3. Can one (1) remote condensing unit be connected to more than 1 unit of different temperatures? _____
4. What does the term "knockdown" mean when referring to walk-in boxes?

5. Cabinet doors are gasketed to make the box watertight. TRUE/FALSE
Why? _____

6. The hot gas defrost system has a direct refrigerant line running directly from the compressor _____ to the _____

Why? _____

7. The line is opened and closed by a _____.
8. Explain the purpose of the "pump down system" and how it accomplishes this.

9. Defrost timers are not needed to start and stop the automatic defrost cycle. TRUE/FALSE.
10. The timers are either 1 day, 1 week, or 1 month design. TRUE/FALSE

STOP! YOU HAVE COMPLETED THE DIRECTED STUDY ASSIGNMENT IN PREPARATION FOR DAY 31.

Directed Study Assignment for Day 32

Construction Features and Operating Principles of Large Reach-In Boxes, Display Cases, and Ice Cream Cabinets

Read the following paragraphs from the "Modern Refrigeration and Air Conditioning" textbook and answer these questions.

Paragraphs 13-2, 13-5 through 13-12.

1. What type of evaporator is used in reach-in cabinets, usually?

2. The exterior of the reach-in is constructed of _____,
_____, _____, and _____.

3. What is the purpose of the blower?

4. Temperature in the display case is determined by _____.

5. Why are electric lights for the display case usually installed outside the case?

6. The three (3) types of display cases are:

a. _____

b. _____

c. _____

7. Where may the evaporator be located in a display case?

a. _____

b. _____

c. _____

8. If bulk ice cream is kept at -20°F. , what problems might be encountered?

9. Ice cream cabinets may be either self-contained or remote. TRUE/FALSE

10. What temperature should packaged ice cream be kept at? _____

Construction Features and Operating Principles of Multiple-Evaporators and Multiple-Compressor Systems

A. Read the following paragraphs and answer the questions.

Multiple Evaporator Systems

Multiple evaporator systems are installed for economy and to save space. It is cheaper to operate one compressor to control the temperature of two or more evaporators than to operate a compressor for each evaporator. Also, having one unit that has two or more temperature areas takes less space than a compressor for each temperature area.

Classifications of Multiple Evaporator Systems

Generally, multiple evaporator systems fall in one of two groups. First, where all evaporators have the same temperature. This is the simplest, although not the most common in use. Second, where each evaporator has a different temperature. This application is found in most multiple installations.

Applications of Multiple Evaporator Systems

Multiple evaporator units are often installed in restaurants, soda fountains, bars, meat and produce markets, and other places where the use of more than one refrigeration fixture is a necessity.

It must not be assumed that any two or more evaporators may be connected in multiple without regard to size, usage, humidity requirement, temperature, and similar conditions. There are some combinations that will not give satisfactory service and must be avoided. However, there is no concrete information that will apply in all cases, but there are certain conditions and rules that must be followed to insure a servicable installation.

1. What are the classifications of multiple evaporator systems?

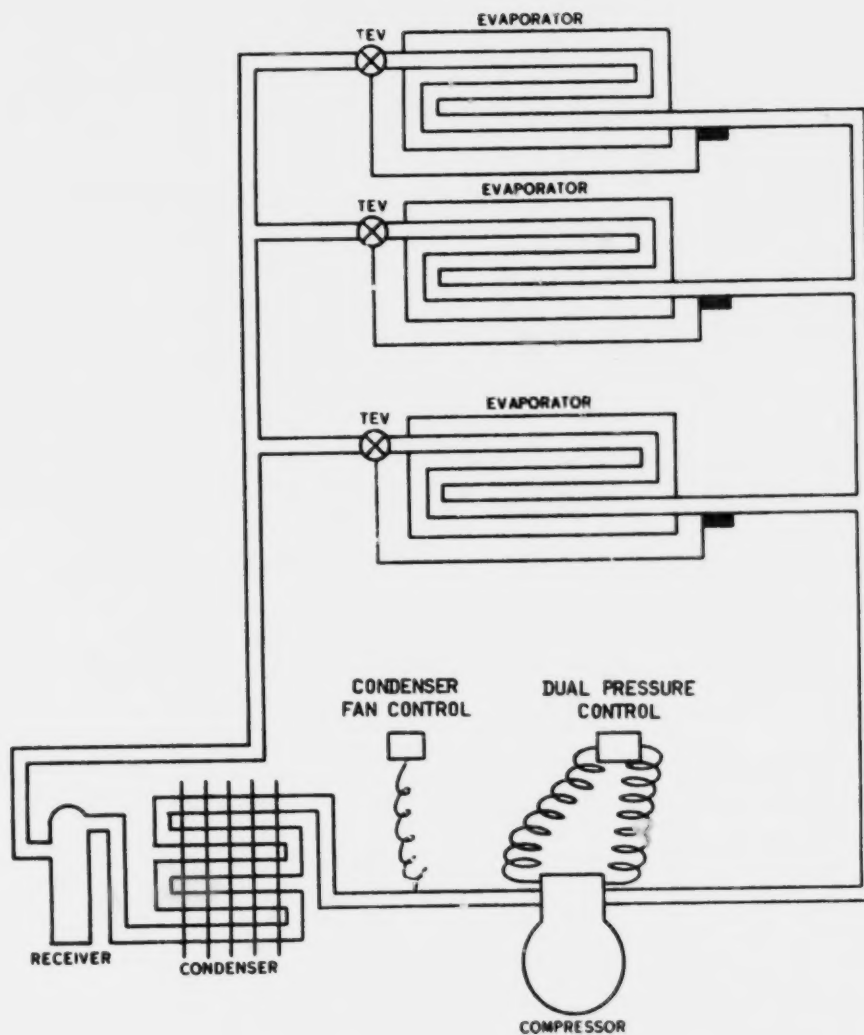
- a. _____
- b. _____

2. Where might you find multiple evaporator units installed?

B. Read the following paragraph and answer the questions.

Single Temperature Evaporator System

A multiple evaporator system may be operated as a single-temperature system. This means that all evaporators will have the same temperature range. In this case, the needs of each evaporator will be controlled by a single-pressure control or thermostat. When all evaporators have been satisfied, the compressor will pull the pressure in the common suction line down to the cutout point of the pressure control. The pressure control contacts then open, stopping the operation of the system. As the pressure builds up in the evaporators, it also builds up in the common suction line. When the pressure in the common suction line reaches the "cut-in" setting on the pressure control, the pressure control contacts close and the compressor starts. When all evaporators are satisfied, the compressor shuts off after the common suction line pressure drops to the cutout point set on the pressure control. This is a continuous process.



Single Temperature Evaporator System

1. On a single temperature system, what controls the box temperature?

How? _____

2. What cycles the compressor?

C. Read the following paragraphs and answer the questions.

Multi-Temperature Evaporator Systems

The successful installation and operation of multiple systems requires the consideration of each application. The units give more efficient operation when installed close to each other. The following suggestions will be found useful as a guide. Due to the large number of possible multiple combinations, it is impossible to give a specific set of rules and expect them to apply in all cases; therefore, it must be understood that there will be exceptions to the following rules:

1. The coldest evaporator must comprise more than half the total heat load. If the warmer evaporator comprised the largest part of the load, the condensing unit would be operating at the higher suction pressure most of the time. The condensing unit would not be able to bring the colder box down to the correct temperature.
2. The condensing unit must be selected to operate at the lowest suction pressure of the coldest evaporator. Since the colder evaporator constitutes the major part of the load, the compressor will be operating at that pressure most of the time. This is another case where it must be remembered that the efficiency of a compressor decreases as the suction pressure decreases.
3. Each evaporator must be selected for a given temperature and humidity. The selection is made just as if each evaporator is connected to its own compressor.
4. A special control is necessary where the temperature difference between the coldest and warmest evaporator is more than 5°F. This control must be either an evaporator pressure regulator or solenoid valve. If the evaporator temperature is the same, but one refrigerator is used more than the other, a control should be placed in the suction line of the refrigerator with the least usage.
5. A snap-action control must be used if defrosting on the "off" cycle is desired.
6. Connect the coldest evaporator closest to the compressor.
7. A check valve should be located in the suction line between the outlet of the evaporator and the common suction line on all but the warmest evaporator. Check valve will prevent warm refrigerant gas from flowing into a colder evaporator coil.
8. Thermostatic expansion valves should be used when direct expansion evaporators are installed.
9. The liquid and suction lines must be sized according to the need as if all evaporators were demanding refrigerant at the same time.
10. A multiple system will operate more efficiently when the temperature difference between the coldest and warmest temperature evaporators is not more than 25°F.

Why is it not recommended that on a multi-temperature multi-evaporator system the warmest box be the largest portion of the total heat load?

What is the recommended distribution of the multi-temperature multi-evaporators in percentage of heat load capacities?

Where should the coldest evaporator be located on a multi-temperature system?

Why? _____

Where should check valves be installed on multiple temperature multiple evaporator systems?

What is their function?

D. Read the following paragraph and answer the question.

Solenoid Valves

Solenoid valves are used extensively in multiple installations in place of/or with evaporator pressure regulating valves. As you remember, evaporator pressure regulating valves can keep the temperature in a refrigerated space from dropping too low by maintaining a constant pressure in the evaporator. The operation of a liquid line solenoid valve is as follows. Assume that the thermostats call for cooling, and that the compressor is operating on all of the evaporators. When one thermostat is satisfied, its contacts open and that solenoid closes the liquid line to that evaporator. The compressor pumps the refrigerant from that evaporator and continues to operate on the others. As each thermostat is satisfied, its solenoid closes and finally when all valves are closed the compressor is stopped by the low pressure motor control.

1. Where are solenoid valves used extensively?
-

E. Read the following paragraphs and answer the questions.

Solenoid Valve Selection

The type of control application requires definite information concerning the valve selection. The fluid to be controlled, capacity needed, maximum working pressure, maximum operating pressure differential (MOPD), and electrical characteristics are factors that must be known.

The selection of a valve depends on whether it is used on liquid or gas, as the specific volume of a gas varies with pressure and temperature. The capacity of a valve is given in tons of refrigeration with a 2-4 psi pressure drop across the valve for liquid and 1 psi for gas.

The MOPD is the pressure against which the solenoid will operate the valve. This pressure is measured between the inlet and outlet of the valve when it is closed. The valve rating must be equal to or better than the maximum operating pressure of the system. The electrical characteristics include voltage, phasing and cycles.

1. What is MOPD?
-

Explain.

2. How is MOPD measured?
-

F. Read the following paragraph and answer the question.

Multi-Compressor

Multiple refrigeration systems cover a lot of territory and can include a simple multiple evaporator system to a multiple temperature, multiple compressor cold storage plant system. These systems will be found at nearly every USAF installation in the world. These types of systems may also be found in air conditioning applications, but are being replaced with more economical forms of air conditioning, such as absorption and centrifugal systems. The advantages of multiple-type systems are numerous:

- Economy of operation at low levels.
- Partial operation in case of unit breakdown.
- Greater capacity control.
- Universal parts replacement.
- Longer life span of the system.

1. Name five (5) advantages of multi-compressor systems.

- a. _____
- b. _____
- c. _____
- d. _____
- e. _____

G. Read the following paragraphs and answer the questions.

Of course, there are some disadvantages:

- Initial cost of installation.
- Complexity of operation and servicing.
- Refrigerant gas and oil complications.

As a service specialist, these problems can be overcome if you follow the basic refrigeration cycle and remember the special requirements for these types of systems. The most common is that the oil equalizer line must be located below the minimum oil level and the gas (crankcase pressure) equalizer line **MUST BE LOCATED ABOVE THE MAXIMUM OIL LEVEL**. Ultra low temperatures can be achieved with special refrigeration systems, such as Direct Compounding (Staging Compressors). This overcomes the volumetric deficiency that is a problem with ultra low temperature systems. Another way of achieving ultra low temperatures is the Cascade System which is two separate refrigeration systems, where the compound system is two or more compressors piped in series (discharging directly into a second compressor or even into a third). The Cascade System involves a refrigeration system that uses an evaporator to act as the condenser (condenser-evaporator) for the primary system. These systems are independent of each other and use different refrigerants such as R-12 in the secondary system and R-13 or some other azeotropic refrigerant in the primary system.

These types of systems are being used more and more today. The Air Force has them at research bases for testing new weapons systems and the civilian industry is using these systems not only in the freeze-dried industry but also in special manufacturing processes.

1. Name three disadvantages of multi-compressor systems.

- a. _____
- b. _____
- c. _____

2. What are the requirements one must keep in mind when installing the oil equalization line and the crankcase pressure equalizer?

Homework in preparation for Day 32.

Read the following paragraphs from the "Modern Refrigeration and Air Conditioning" textbook. Be prepared to discuss material and answer questions in classroom on the assigned material.

Paragraphs 5-19, 5-20, 5-30, 5-31, 12-2, 12-3, 12-45 thru 12-54.

STOP! YOU HAVE COMPLETED THE ASSIGNMENTS IN PREPARATION FOR DAY 32.

Directed Study Assignment in Preparation for Day 33

Procedures for Installing Multiple Compressor and Installing Multiple Evaporator Systems

A. Read the following paragraphs from the "Modern Refrigeration and Air Conditioning" textbook and answer these questions.

Paragraphs 14-1, 14-3, 14-9 through 14-13.

1. What should the 2 major concerns be on a commercial installation?

2. List the 10 basic installation steps for a commercial unit.

a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

g. _____

h. _____

i. _____

j. _____

3. What are the 4 methods to check for leaks in a system?

a. _____

b. _____

c. _____

d. _____

4. What are the 2 basic methods of charging a multiple commercial system?

a. _____

b. _____

Purpose and Principle of Operation of the Evaporator Pressure Regulator Valve (EPR)

A. Read the following paragraphs and answer the questions.

EVAPORATOR PRESSURE REGULATOR MULTI-TEMPERATURE SYSTEM

The refrigerant flow is controlled by evaporator pressure regulators in this system. The evaporator pressure regulator (EPR) valve is the oldest and perhaps best known of these suction line controls. Its sole function is to prevent the evaporator pressure from falling below a predetermined pressure for which the regulator has been set. The EPR maintains a constant pressure in the evaporator coil. It may be used on a multiple system to maintain certain minimum pressures on individual evaporators.

Operation of the EPR

When the cutout temperature of an evaporator is determined, the EPR valve is adjusted. As the compressor operates the pressure in the evaporator is lowered. When it reaches the cutout point of the evaporator, the valve will close. This stops the flow of refrigerant through this evaporator. As the temperature and pressure rises in the evaporator, (it tends to force the valve off its seat). This will hold the evaporator pressure constant because of the gradual movement of refrigerant. If the gradual flow of refrigerant is sufficient to make the pressure in the common suction line increase to the cut-in point of the motor control, the compressor will operate. This will pull the pressure down to the cutout point. If there is a rapid evaporator pressure increase because of the addition of a high heat load, the valve will open all the way. This directs the evaporator pressure to the common suction line where it is pulled down to the cutout point of the compressor. The valve will close when the evaporator is cold enough.

1. What is the sole function of an EPR valve?

2. The EPR maintains a _____
in the evaporator coil.

3. What must be determined to adjust the EPR?

B. Read the following paragraphs from the "Modern Refrigeration and Air Conditioning" textbook and answer these questions.

Paragraphs 12-45 thru 12-54; 12-56

1. What is another name for a two-temperature valve? _____
or _____.

Operation of Multi Evaporator Systems

Read the following paragraphs and answer the questions.

Single Temperature System. Since all the refrigerated compartments in this system operate at the same temperature, the compressor must be cycled by a low pressure motor control rather than a thermostat. The low pressure motor control will sense the pressure in the common suction line that is connected to all the evaporators in the system, cut in the compressor when the evaporators reach the highest desired temperature, and cut out the compressor when the evaporators reach the lowest desired temperature. Using the pressure of the common suction line to cycle the compressor, the system acts like a single evaporator system.

1. How is the compressor cycled on a multi-evaporator, single temperature system?

To set the low pressure motor control to operate a single temperature multi evaporator system, you could simply convert the desired cut-in and cut-out evaporator temperatures to pressure and adjust the pressure control to the correct settings. (Example: If your desired cut-in box temperature is 45°F, and your desired cut-out box temperature is 35°, you would convert 45°F to 42 psig and adjust the low pressure motor control cut-in to that pressure. While the unit is operating, there is a 10°F temperature difference between the box temperature and evaporator temperature, so you would convert 25° evaporator temperature to 25psig, and adjust the pressure control cut out to that pressure, using R-12.

A drawback to using this quick method of setting the low pressure motor control is the possibility of a pressure drop between the evaporator and the pressure control. If your system has a 3 psi pressure drop, the box temperatures would operate too warm by about 5°F.

1. What is a disadvantage to using the quick pressure/evaporator temperature conversion method to adjust a low pressure motor control?

A more time consuming, but more exacting method of adjusting the low pressure motor control is to operate the system, and using a thermometer located inside the refrigerated space, allow the unit to warm up to the cut-in box temperature, and adjust the pressure control to cut the unit in at that temperature. Allow the system to cool down to the desired cut out box temperature and adjust the pressure control again to cut the unit out at that temperature.

1. What is the advantage to using the operational method to adjust a low pressure motor control?

The expansion valve on each evaporator in this system must be balanced with each other, that is, they all must operate at the same superheat setting. The best way to adjust the superheat setting of the valves so that they are identical is to remove each of them from the system and calibrate them on an ice bath test stand.

1. Why should the thermostatic expansion valves on a single temperature, multi evaporator system be calibrated on an ice bath test stand?

STOP! YOU HAVE COMPLETED DIRECTED STUDY ASSIGNMENT IN PREPARATION FOR DAY 33.

Directed Study Assignment in Preparation for Day 31

Read the following paragraphs and answer the questions. Be prepared to discuss this information in class.

Evaporator Pressure Regulator Adjustment

It was explained in an earlier lesson that evaporator pressure regulator valves are installed in the suction line of the warmer evaporators and thereby, increasing its temperature. When adjusting an EPR valve, turning the adjustment clockwise will increase the evaporator pressure and temperature. A counter-clockwise adjustment will result in a lower evaporator pressure and temperature. Modulating type EPR valves are adjusted to the lowest desired evaporator temperature converted to pressure. Remember, there is a 10°F temperature difference between box temperature and evaporator temperature.

1. How is an EPR valve adjusted to lower the evaporator pressure?

There are two methods used to adjust an EPR valve. The quick method is where you subtract 10°F from the lowest desired box temperature, convert to pressure, and adjust the EPR valve to that pressure.

The other method which is slower, but more accurate is to use the refrigerated space thermometer and adjust the EPR valve as required to prevent the box temperature from dropping below the desired value.

1. When using the quick method to adjust an EPR valve, why is 10°F subtracted from the lowest desired box temperature?

While operating a multi-temperature system, you may encounter a stuck EPR. It may be stuck open or closed. If the EPR is stuck closed, you will notice the box temperature is too high, and the suction pressure will be below normal or in a vacuum. A stuck open EPR would be indicated by a too cold box temperature. The suction pressure would be low this time too, but not in a vacuum. To service a stuck EPR valve, you would clean or replace it.

1. How is a stuck closed EPR valve indicated?

2. How do you service a stuck EPR valve?

Operation of Multi-Compressor Systems

Read chapters 3-13 in the "Modern Refrigeration and Air Conditioning" textbook, and answer the following questions.

1. What is the purpose for using a multi-compressor or modulating system?

2. Using a modulating, or a multi-compressor system, during operation, describe what would happen if the heat load increases and the temperature begins to rise.

3. What is the purpose of the special switching device in the pressure control in figure 3-13?

Read chapter 12-4 in the "Modern Refrigeration and Air Conditioning" textbook. List the types of two-motor compressor designs, and explain each design.

STOP! YOU HAVE COMPLETED DIRECTED STUDY ASSIGNMENT IN PREPARATION FOR DAY 34.

Directed Study Assignment in Preparation for Day 35.

Read the following paragraphs and answer the questions. Be prepared to discuss the information in class.

Multi-Temperature System. Because the refrigerated compartments of this system are operating at different temperatures and are using only one condensing unit, temperature and pressure control are more complicated and more control devices are required.

Control of the various temperature ranges in this system is accomplished by a thermostat liquid line solenoid valve arrangement. Each refrigerated space will have a thermostat, and the liquid line to each evaporator will have a solenoid valve which, when deenergized, will block the flow of refrigerant to that evaporator, effectively shutting that evaporator off. The box thermostat is wired in series with its solenoid valve. When the thermostat calls for its space to be cooled, the thermostat contacts close, energizing the solenoid valve to that evaporator. Refrigerant is now allowed to be metered to the evaporator, and the box temperature will reduce until it reaches the temperature at which the thermostat contacts open, deenergizing the solenoid valve, stopping the flow of refrigerant to that evaporator. When all the different temperature areas have been satisfied, the low side pressure will have dropped enough for the condensing unit to cycle off on the low pressure control.

1. How is the temperature in the different refrigerated spaces controlled in the multi-temperature system?

2. What component shuts off the evaporator when the refrigerated space is down to desired cut-out temperature?

3. What happens when all the refrigerated spaces are satisfied?

There are two operational controls that have to be adjusted for proper operation of the multi-temperature system.

The refrigerated space thermostat must be set to stop refrigerant flow when the lowest desired temperature is reached, and begin refrigerant flow when the highest desired temperature is reached. There are different ways to adjust a thermostat depending on the manufacturer. On some types, you set the cut-out temperature, and then by adjusting the differential you also set the cut-in temperature. Other manufacturers build a cut-in, and cut-out adjustment on the thermostat.

1. What does the refrigerant space thermostat control?

2. Using the cut-out and differential type thermostat, how is the cut-in set?

The other operational control that must be adjusted on the multi-temperature system is the low pressure motor control. In comparison, on the single temperature system, this control is used to control the refrigerated space temperatures. In the multi-temperature system, temperature control is accomplished by the thermostat -solenoid valve circuit, and the low pressure motor control is used to shut off the condensing unit after all the evaporators have been shut off. The pressure control should be adjusted to shut down the unit before the system goes into a vacuum. It is normally adjusted to cut out the unit when the suction pressure drops to within a range of 1-5 psig. The cut-in of the low pressure motor control on this system is adjusted to the suction pressure equal to the highest desired temperature of the coldest refrigerated space. Remember to adjust the cut-in first. This method of adjusting the low pressure motor control will prevent the condensing unit from short cycling during the off cycle.

1. Compare the use of the low pressure motor control on the two multi-evaporator systems.

2. On the multi-temperature system, the cut-in is adjusted to what value?

3. On the same system, the cut-out is adjusted to what value?

4. On the low-pressure motor control which adjustment is always set first, the cut-in or the cut-out?

Technical Training

Refrigeration and Cryogenics Specialist

FUNDAMENTALS OF AIR CONDITIONING

December 1983



3700 TECHNICAL TRAINING WING
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

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CIVIL ENGINEERING MAINTENANCE MANAGEMENT

OBJECTIVE

This study guide/workbook will acquaint you with basic facts and terms related to Civil Engineering Maintenance Management functions.

INTRODUCTION

The primary mission of Civil Engineering activities is to acquire, construct, maintain and operate real property facilities, and provide related management, engineering and other support work and services.

DIRECTED STUDY AND HOMEWORK

Assignment in preparation for Day 36. Read the following paragraphs, answer all questions and be prepared to discuss the material.

AFR 85-10, Operation and Maintenance of Real Property, states that "...effort required to carry out the Civil Engineering mission and functions depends on the proper balance of...military and civilian personnel..."the military element of this force, which ordinarily acts as an integral part of the total work force, is used with the civilian element (through established work centers) in doing any authorized base civil engineer work.

Military personnel are used primarily for direct combat support roles in support of the Air Force mission under the Prime Base Engineer Emergency Force (Prime BEEF) concept. The Prime BEEF program is designed to identify, organize, equip, and train the military element of base civil engineer personnel resource. Military personnel are used in direct mission support, as well as areas cited for civilians, when not deployed to satisfy other mission requirements.

Work task of military personnel should be diversified enough to maintain competence necessary for these personnel to carry out their direct combat support roles.

Civilian personnel are used primarily to perform maintenance and repair incident to the maintenance of real property facilities, structures and equipment, and to operate the base utility system. Civilians may also be used to perform minor construction, to do repairs not incident to maintenance, and to do other related work.

QUESTIONS

1. The Prime BEEF program is designed to _____
_____.
2. Civilian personnel are used primarily to perform maintenance and _____
_____.

AFR 85-1, Resource and Work Force Management, identifies work to be done in six areas of responsibility. However, at this point you need only be concerned with three of these areas.

The Job Order System is a fast way to authorize work that does not require detailed planning. The system indicates emergency, urgent, and routine precedence work calls. Also, there is included in this system, Structural Maintenance, Repair Team (SMART), and Military Family Housing renovation job orders, which will not be discussed here.

Service calls are generated by customer telephone requests which are identified on AF Form 1879, BCE Job Order Record.

BCE authorized work to be done by BCE work orders and BCE job orders. AF Form 327 (BCE Work Orders) is used to authorize work that needs detailed planning. It is a way to control large complex jobs. AF Form 332 (BCE Work Request) is used to request minor construction work and authorize self-help work (construct sidewalks, install alarm systems, etc.). AF Form 1135 (BCE Real Property Maintenance Request) is used for maintenance and repair of real property equipment which is of a routine priority only (replace door, repair flooring, repair or replace window, etc.).

QUESTION

How are service calls received by BCE?

When received by telephone, service calls are authorized by Service Call Specialist (SCS) on AF Form 1879, Job Order. Other job order work requests are prepared by the Customer Service Unit (CSU), also on AF Form 1879.

Emergency or urgent job order precedence is assigned to conditions that require rapid corrective action.

Any work required to correct a condition that is detrimental to the mission or reduces operational effectiveness is deemed to be an emergency situation. When reported emergency service calls are serviced as soon as possible, and must be completed within forty-eight hours of having been reported.

Urgent job orders identify work that is not emergency in nature, but work must be accomplished within five work days.

QUESTIONS

1. What is the criterion used to determine an emergency service call? Within how many hours must an emergency service call be completed?
2. Urgent service calls must be completed within _____.

Routine job orders are accumulated by geographical area and scheduled as work packages rather than individual job orders, and are serviced within thirty days of receipt on a first-in, first-out basis.

QUESTION

Routine work orders should be assigned by _____.

Materials required for a particular job are controlled by the BCE Material Control Section. A material control section within BCE is charged with the responsibility to process requests for material, monitor the status of requirements, and provide information on the availability of materials.

BCE Material Control Section retains job or work order material in a "holding area." A holding area is a storage facility for material or equipment required to accomplish a particular job. All materials for work or job orders are stored in the holding area except items on bench stock or minimum reserve authorization (MRA) list. When job has been scheduled for accomplishment, materials are released to each appropriate shop.

FUNDAMENTALS

OBJECTIVE

To familiarize you with types and purpose of air conditioning equipment, procedures for installing air conditioning equipment, psychrometrics, insulation, filters, fans, air flow instruments and maintenance of fresh air systems.

INTRODUCTION

Air conditioning is defined as "that process used for the control of temperatures, humidity, filtration, and circulation of air." Air conditioning is playing a more important part in man's environment. His home, automobile, business and recreational locations are air conditioned in order that the maximum comfort may be maintained, increasing the efficiency of the activity being performed.

Air conditioners are designed to fulfill the definition that "air conditioning is the control of temperature, humidity, filtration, and circulation of air." There are several applications for air conditioners, they include:

Types and Purpose of Air Conditioning Equipment

There are four types and purposes of air conditioning equipment. All four groups may be found on the same system.

TEMPERATURE CONTROL EQUIPMENT

This portion of air conditioning equipment will add or remove heat to or from the conditioned space. To remove heat the air conditioner will use the same basic cycle as a refrigerator. The operational evaporator temperature range will run between 40 and 50°F (4.4 to 6.5°C). There are two methods of picking up heat from the conditioned space. The first method will place the evaporator in the conditioned space, this method will be discussed in this block. The second will circulate chilled water through coils in the conditioned space returning the water to a specially designed evaporator for cooling and recirculation. This method will be discussed in another block.

To add heat to the conditioned space, two methods are also used. First, furnaces will heat the conditioned space directly using natural gas, oil, propane, butane, or electricity. Second, steam or hot water will be circulated through coils in the conditioned space and returned to a boiler to be heated and recirculated.

Humidity Control Equipment

Humidity control equipment has two functions. First, remove humidity. The most common method of humidity removal is to operate the air conditioner's cooling system. The low temperature of the evaporator will cause condensation, thus removing humidity. Second is to add humidity. There are two methods of humidifying. One method is to inject steam into supply air. The other method passes air over a wetted pad or sprays water into ducts.

Air Filtration Equipment

Air filtration equipment may have two purposes. First air filtration equipment is installed in air circulation equipment to help keep evaporators, fans, and heating coils clean. Second, special air filtration equipment may be installed to meet special requirements of the conditioned space. Some examples of this type equipment are high efficiency filters designed for use in computer rooms, or ultra violet filters used to sanitize air for surgery rooms in the base hospital.

Air Circulation Equipment

Air circulation equipment defined means equipment that moves air. As you know, fans move air so this will be the subject of this paragraph. First let's discuss the types of fans. Centrifugal fans are commonly known as squirrel cage fans due to their appearance. Axial fans are sometimes called propeller fans because the blades look like propellers. Each of these types of fans will be discussed later.

Installation

Sometime in the course of your duties, you may be called upon to install, or help install air conditioning equipment. You should be aware of some general guidelines concerning the installation of air conditioning equipment.

Condensing Unit

When installing a condensing unit, be sure that it is installed level, provides proper air circulation for air cooled condensers, assures that the electric motors voltage, cycle, and phase are of the same value as the power source.

Evaporator

The evaporator should be installed so that it is level, and firmly fastened. It must be provided with a drip pan to catch condensation formed during the cooling cycle.

Fans

When installing a fan and motor, assure that they are mounted on a common base in order to insure a permanent alignment. The motor should be on a sliding mount for belt adjustment. Large fans should be installed in a location remote from the conditioned space if possible.

Filters

Install the filter section so that the air must pass through the filters before entering the heating/cooling coils and fan.

Security of Mounting

When installing air conditioning equipment, it is important that securing of refrigerator, water, electrical lines and system components be assured. Tubing should be supported at regular intervals to prevent sagging and vibration. Vibration will cause copper tubing to crystallize which in turn causes the tubing to crack or break. Hard drawn copper lines need fewer clamps or supports than soft drawn lines. Tubing can be supported by using regular tubing clamps, or galvanized conduit clamps may be used. When supporting tubing with clamps, the tubing should be insulated from the clamps to prevent damage to the tubing from the clamps. A piece of rubber insulation inserted between the tubing and the clamp is sometimes used. Tubing run through a wall or floor should be protected by short runs of conduit or flexible metal tubing. Valves, driers or other heavy objects should not be supported by tubing, but should have their own individual supports. Electrical lines should be supported similar to tubing.

Psychrometrics

The purpose of air conditioning is to control temperature, humidity and the circulation of the air.

Air is the primary medium that is used to control the conditions in the controlled space. Air can be used to control the humidity and temperature for three general uses: personnel or comfort cooling, equipment cooling, and process cooling. In the case of equipment cooling, temperature and humidity must be maintained within close tolerance. New applications for air conditioning are continually being found.

The field of psychrometric study is a breakdown of the various properties contained in the air and a graphic analysis of the air conditions. If the specialist understands all he can about the air being used, the understanding of the equipment operation becomes more realistic.

Psychrometrics is defined as the study of air and its related properties. As you know, air contains some moisture (humidity). However, let us consider the other properties relating to graphic analysis of moisture-laden air. Air is a mixture of highly superheated gases. About 78 percent of the air is nitrogen, 21 percent oxygen, and the remaining one percent is composed of minute quantities of other gases such as carbon dioxide, argon, neon, ozone, hydrogen, helium and krypton. All of these form the air that we breathe and use for air conditioning. Air exerts a force of 14.7 psia on the surface of the earth at sea level. Air and water vapors are mixed, occupying the same space and following Dalton's law of partial pressures, "The pressure of a mixture is the sum of the partial pressures of the constituent gases" Vapor pressures are regulated by the movement of the molecules at the surface of the substance. For example, water at a temperature of 212°F has a vapor pressure of 14.7 psia.

QUESTION

What is psychrometrics? _____

Temperature of the Air

Temperature is the measurable intensity of heat contained in a volume of air, read in degrees. It can be expressed as degrees Fahrenheit or Centigrade, depending on the scale being used. In the psychrometric analysis such temperatures as dry bulb, wet bulb, dew point, saturation and apparatus dew point temperatures will be considered.

Humidity of the Air

Humidity is the moisture vapor contained in the air. There is, generally speaking, two humidity expressions: specific humidity is the actual moisture contained in the air or the grains of moisture content; the relative humidity is an expression of the specific humidity in relation to the volume.

Heat Content of the Air

This term refers to the heat contained in a given condition of air. It is measured in British thermal units (BTU). It is also expressed as the enthalpy. Remember, that a BTU is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. Based on this standard are other standards such as one ton of refrigeration. We know that it will take one ton of ice 24 hours to change from 32°F ice to 32°F water, and that it will absorb 288,000 BTUs during that time. This means that BTUs were absorbed at the rate of 12,000/hr, 200/min, or 3.33/sec. Any of these values means one ton of refrigeration.

Volume of the Air

Air, as any substance, must occupy space. This space is volume and is expressed in cubic feet. The volume of air will vary with the heat contained in the air. As the temperature increases so does the volume, provided room for expansion exists. If there is no room for expansion, the pressure will increase due to the limitations imposed by the containing device.

In the case of unconfined air, the pressure remains constant. The air volume changes with the heat content. A volume of air contracts or expands 1/460 of its volume at 0°F for each degree of temperature change. If absolute zero (-460°F) was reached, the volume would shrink to zero as well. Although this is strictly theoretical and has never been achieved, it does point out the relationship of temperature to volume. Specific volume is the number of cubic feet of air that it takes to weigh one pound.

Weight of the Air

If the air has all of the foregoing properties, then it must be concluded that it has weight. This weight is referred to as specific density. The psychrometric chart will provide the basis for computing of dry air. The weight of the air is dependent on the amount of moisture divided by the specific volume obtained from the chart. If the SV is 13.5 cubic feet, then the SD will be .075.

$$\frac{.075}{13.5/1}$$

It can be noted that as the specific volume increases, the density of the air will decrease.

QUESTION

What are the five properties of air? _____

Psychrometric Chart

The chart is the tool used to analyze the relationship of the properties of the air. The specialist should master at least the meaning of the chart in order to properly understand the air that is being conditioned.

The relationships of the properties of the air are graphically illustrated on the psychrometric chart as a series of lines and curves that have been scientifically formulated to show the whole picture of the air being studied.

The comparison of the lines and curves at intersecting points of the scales on the chart gives us a very comprehensive analysis of the air being studied. More than one condition may appear on the chart to give us more accurate analysis and true operation of the system in consideration.

Sling Psychrometer

The psychrometer is the instrument that is most often used to obtain the basic values needed to work a psychrometric problem. The sling psychrometer (see figure 1) is an instrument that is very basic in design and operation. There are two standard thermometers mounted on a holder with provisions for the device to be whirled in the air. One of the thermometers has a sock attached to the bulb, which is moistened in distilled water prior to slinging of the instrument. The slinging of the instrument will pick up two temperatures. One is ambient or dry-bulb temperature; the second, wet-bulb temperature.

The operation of the psychrometer is very simple. The wet-bulb sock is saturated with distilled water (because there are no mineral deposits in the water that will form residual scale deposits following evaporation). Then, the instrument is whirled in front of the individual for about one minute, read and then whirled for another minute and read a second time.

During this process, air passing through the sock causes evaporation. The evaporation will cool the temperature of the wet thermometer below the dry bulb temperature, depending on the amount of moisture that is in the air being measured. The drier the air, the higher the evaporation rate, the lower the wet-bulb temperature will be. The second reading helps insure that the maximum evaporation rate was attained.

The difference between wet-bulb temperature and dry-bulb temperature is known as wet-bulb depression.

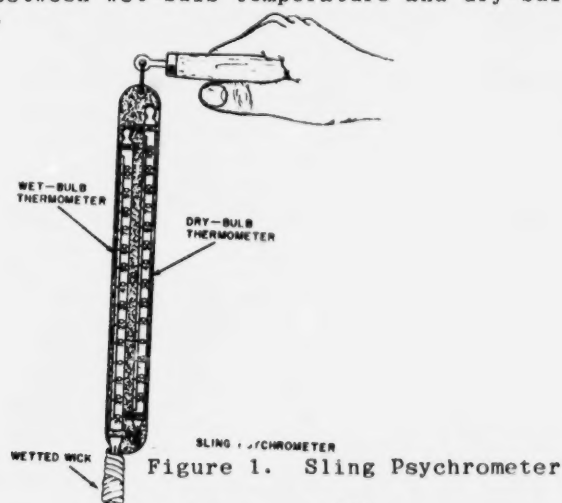


Figure 1. Sling Psychrometer

Psychrometric Chart Scales

Once the dry bulb temperature and wet bulb temperature have been obtained, we can then begin the plotting procedure. In order to know what we are doing, the scales that are read on the psychrometric chart are the first point of identification on the chart. The psychrometric chart contains lines and curves which have corresponding scales and are read at intersecting points.

In figure 2, the lines and scales are identified, then the later figures that accompany the terms and definitions will point out the names of the lines corresponding to each set of scales. There are basically five sets of scales that are used on the psychrometric chart. Some of the readings will be scale differential readings.

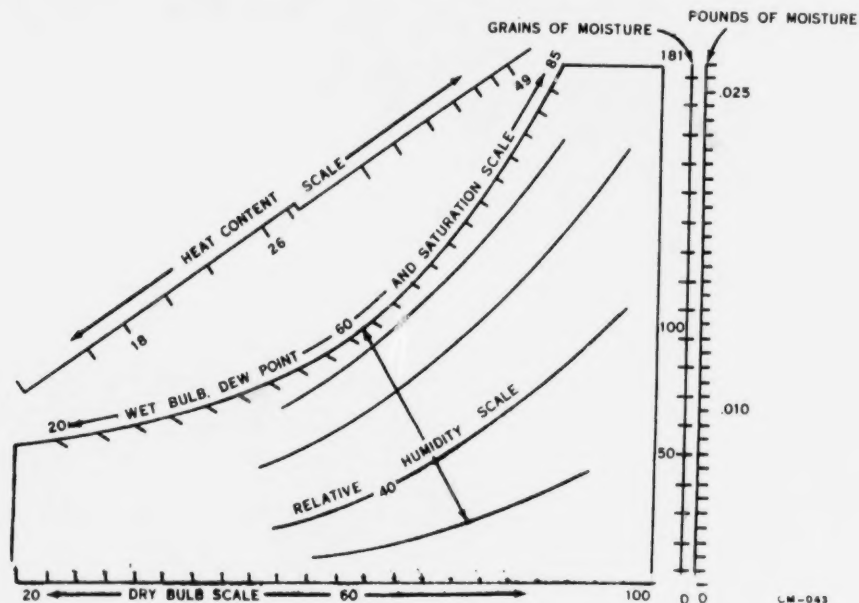


Figure 2. Psychrometric Chart Scales

TERMS, DEFINITIONS AND PLOTS

Dry-Bulb Temperature (DB)

Dry-bulb temperature is the ambient air temperature read on a standard thermometer. Dry bulb plots will appear on the vertical lines of the chart which correspond to the dry bulb scale located along the bottom of the graph. Dry bulb is plotted by locating the indicated condition on the scale, and drawing a vertical line corresponding to the temperature value as shown by the heavy line in figure 3.

Figure 3 is a representative sketch of the dry bulb temperature portion of a psychrometric chart. A complete psychrometric chart has a vertical line for each degree of temperature. Usually, every fifth line is numbered with its corresponding temperature. The common range for a psychrometric chart is from about 10°F to 105°F. This type of arrangement makes it simple to plot any dry bulb temperature on the chart to the nearest degree. The remaining figures in this series are also sketches and do not include all the lines on the psychrometric chart.

QUESTION

What is dry bulb temperature? _____

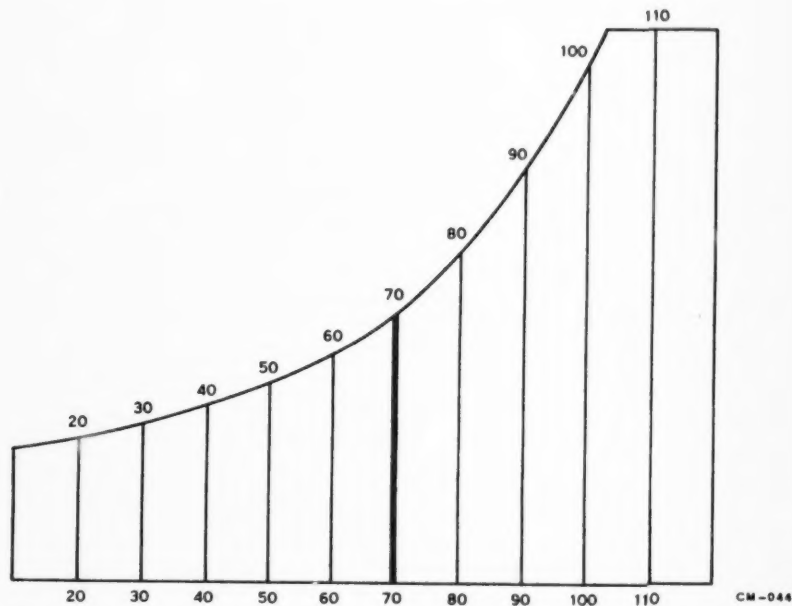


Figure 3. Dry Bulb Line

Wet Bulb Temperture (WB)

Wet bulb temperature is the temperature at which air ceases to be cooled by the process of evaporation. Wet bulb temperature is determined by the sling psychrometer previously described in this section. Keep in mind that the sling psychrometer can only be used effectively if the ambient temperature is above 32°F because the freezing point of water is any temperature below that point. You will notice the slope of the psychrometric chart changes to smaller increments as temperature values given on the saturation or wet bulb scale. To plot a wet bulb temperature, start with the corresponding temperature reading on the wet bulb scale. The wet bulb temperature is plotted on the diagonal line that extends to the right and downward from the wet bulb scale. A wet bulb plot is shown by the heavy line in figure 4. It is not necessary to extend the wet bulb line past its intersection with a previously plotted dry bulb line.

QUESTIONS

1. What is wet bulb temperature? _____

2. Where is the wet bulb plotted? _____

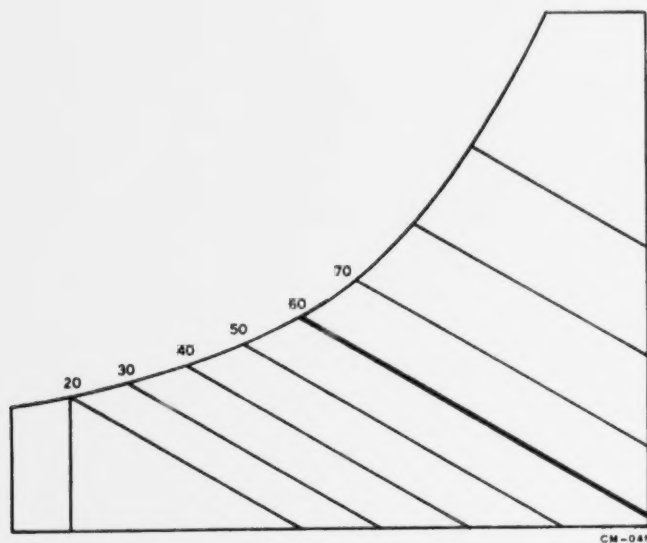


Figure 4. Wet Bulb Line

Relative Humidity (% RH)

Relative humidity is the ratio of the amount of moisture in the air compared to what it could hold at the same temperature.

It is a percentage expression of the grains of moisture contained in the air. Relative humidity is read on or between the curved lines on the psychrometric chart that corresponds approximately to the saturation curve at the point of intersection of the wet bulb and dry bulb lines. They are valued from 0-100 percent. The saturation curve is the 100 percent RH line. Relative humidity is read at the point of intersection of the dry bulb and wet bulb lines.

QUESTION

What is relative humidity? _____

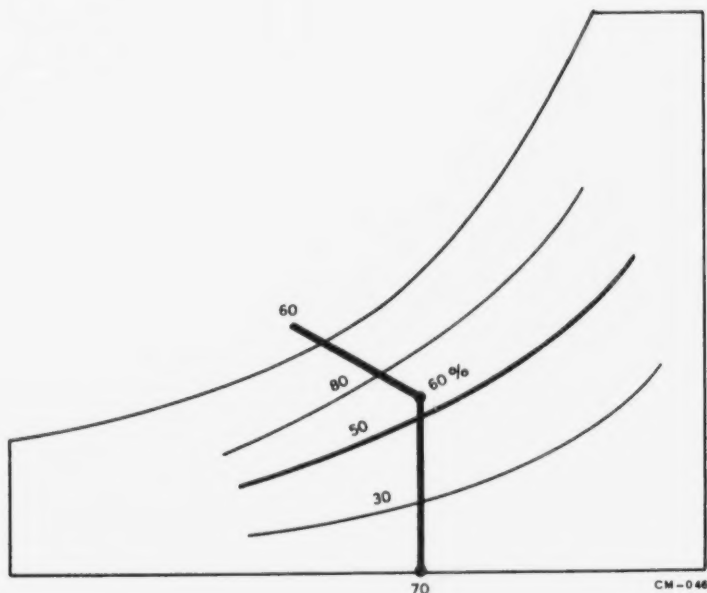


Figure 5. % Relative Humidity

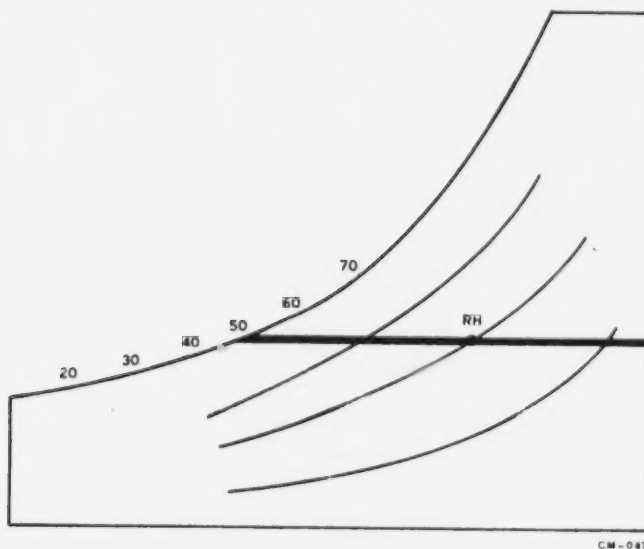
Dew Point (DP)

Dew point or saturation temperature, both terms mean the same. Dew point or saturation temperature is the temperature that will allow moisture to condense on a surface. This is exemplified by the droplets of moisture, called dew found on the grass in the warmer months, or by the frozen dew (frost) in the winter months. Windows or containers that sweat have an extreme of temperature on each side of the surface and are examples of dew point temperature being reached. Dew point is plotted on the horizontal line of the psychrometric chart that extends from the point of % RH to the saturation curve and the value is read at the point of intersection with the curve (see figure 6).

QUESTIONS

1. What is dew point? _____

2. How is dew point plotted? _____



CM-087

Figure 6. Dew Point Line

Heat Content or Enthalpy

Both terms mean the same. Heat content is the measure of the BTU contained in one pound of dry air. Heat content is plotted by extending the wet bulb line through the saturation curve to the heat content or enthalpy scale located to the left of the saturation scale. Read the BTU value at the point the extended wet bulb line intersects the heat content scale as shown in figure 7.

QUESTION

Heat content is the measure of BTU in what? _____

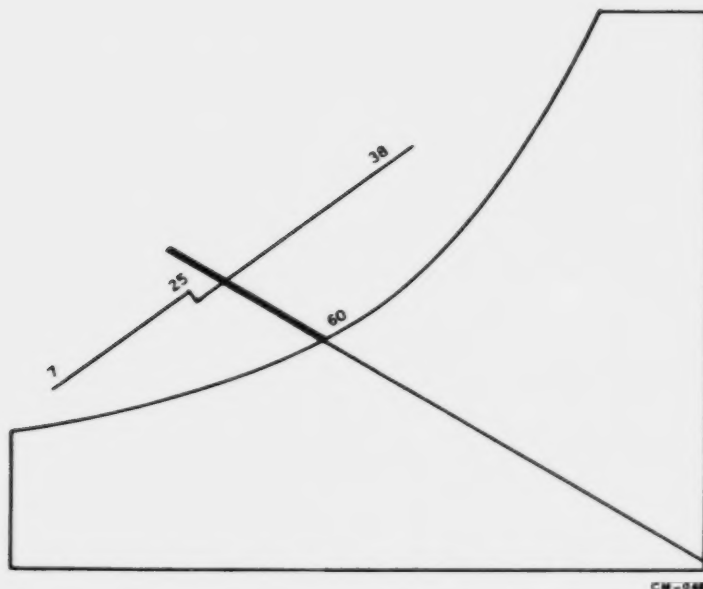


Figure 7. Heat Content Line

Grains of Moisture (GM)

Grains of moisture or specific humidity--both terms mean the same. Grains of moisture or specific humidity is the unit of measurement expressing the actual amount of moisture contained in one pound of dry air. Relative humidity can be determined from this measurement, but you use % RH to determine grains of moisture. A grain of moisture is about the same as a drop of water. A pound of water (about one pint) contains 7,000 grains. To plot grains of moisture contained per pound, draw a horizontal line from the point of % RH to the grains of moisture scale and read the intersecting value on the chart (see figure 8).

QUESTION

How many grains does a pound of water contain? _____

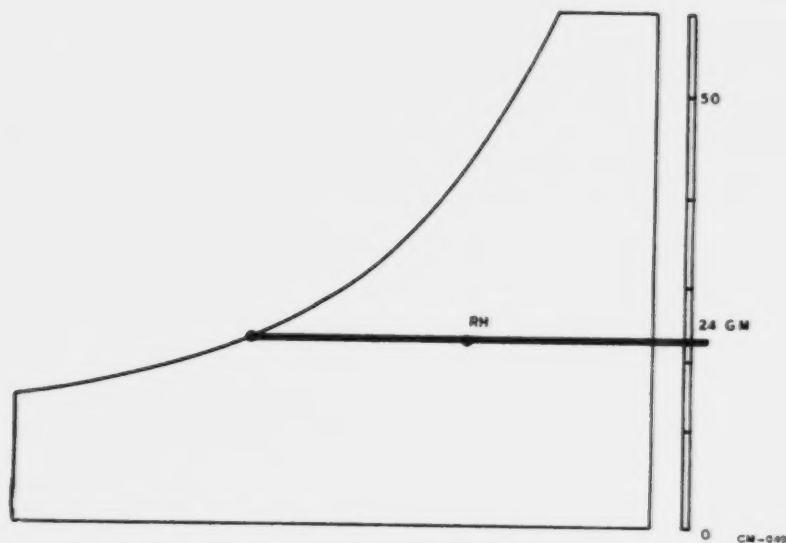


Figure 8. Grains of Moisture

Pounds of Moisture

Pounds of moisture per pound of dry air is the weight of the grains of moisture contained in one pound of dry air. It is determined by drawing a horizontal line from the grains of moisture plot to the pounds of moisture scale and reading the corresponding value at the point of intersection with the scale (see figure 9).

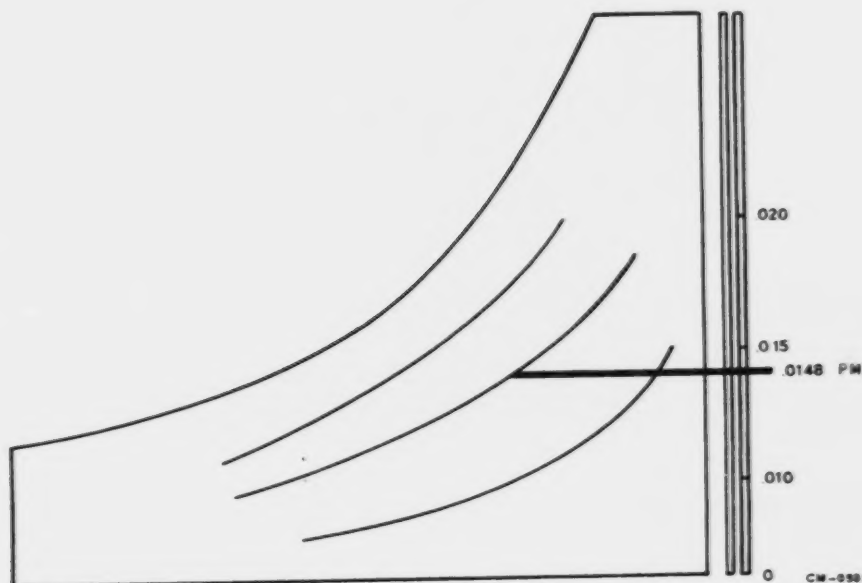
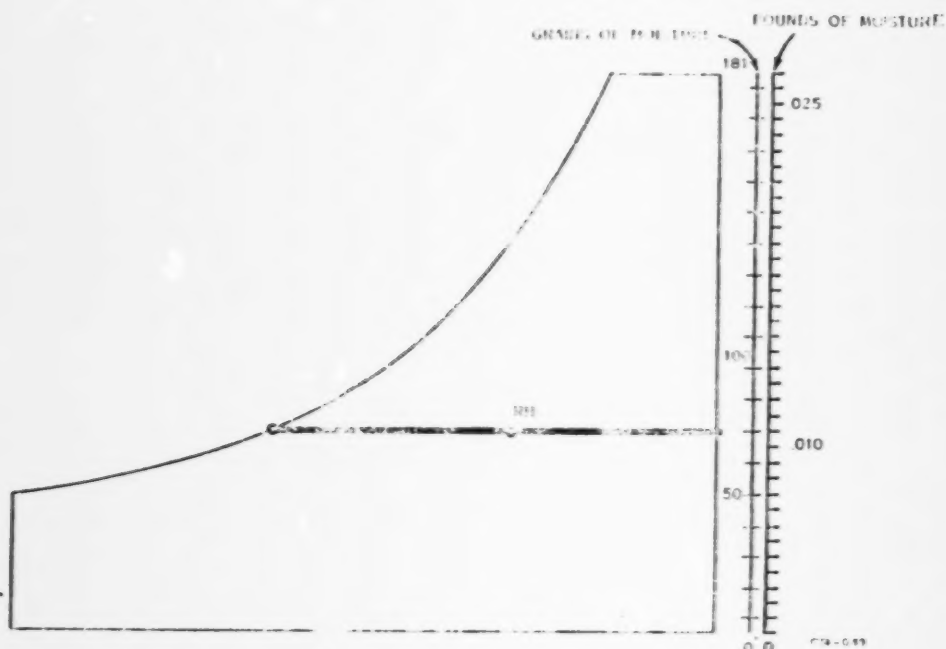


Figure 9. Pounds of Moisture Line

The chart below depicts specific humidity with grains of moisture and pounds of moisture. It shows how grains of moisture values convert into pounds of moisture values.



Specific Volume (SV)

Specific volume is the number of cubic feet of air required to weigh one pound. The specific volume lines appear as diagonal-parallel lines extending from the saturation curve to the dry bulb scale. There are five of these lines and they have a corresponding value of 12.5 cu ft through 14.5 cu ft reading from left to right (see figure 10). To plot specific volume, draw a line parallel to the established specific volume lines from the point of % RH to the dry bulb scale.

To read specific volume plots, start with the specific volume line to the left of the new plot. For every degree Fahrenheit graduation on the dry bulb scale, add .025 until you reach the new line that you drew. Each group of four graduations will increase the specific volume .1 cu ft. Five groups of four graduations will raise the volume .5 or to the next established line of the chart (see figure 11).

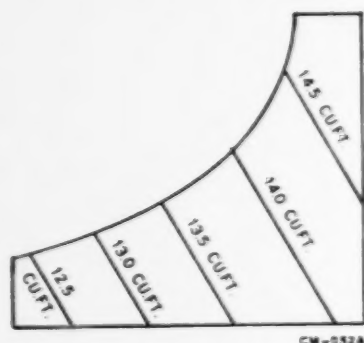


Figure 10. Specific Volume Lines

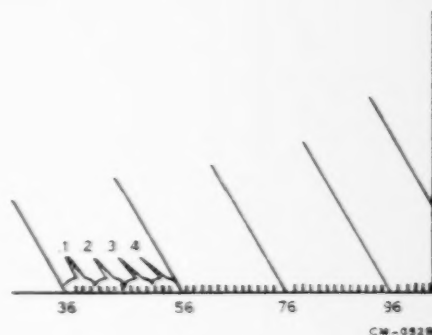


Figure 11. Specific Volume Scale

Standard air is one pound of dry air at 70°F, at atmospheric pressure (14.7 psia) which occupies 13.34 cu ft and has a specific density of .075 at sea level (see figure 12).

14.7 PSIA

70°F

0.075 lb DENSITY

13.34 CU FT

1 LB OF AIR

CM-052C

Figure 12. Standard Air

At this point we have defined the lines and the scales that we will use on the chart. Figure 13 shows a composite of the lines discussed and the relationship of the various lines and scales to each other. This figure shows only a single plot, but psychrometric analysis will involve two to four plots in order to compare all of the temperatures and properties.

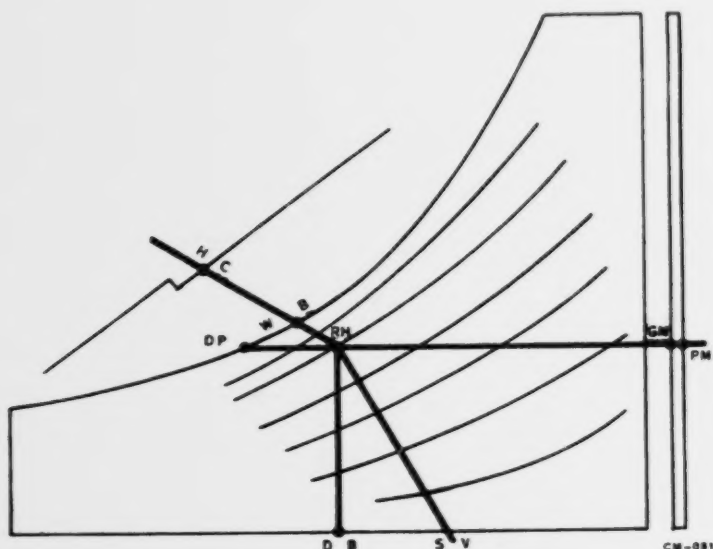


Figure 13. Psychrometric Plot

To have a good comparative analysis of the air, we must be able to identify the various names given to the air as it goes through the system. Air at outside conditions is called Outside Air (OA). It is introduced into the system through the ducts and various plenums, taking on other names during its travels.

Supply Air (SA) (air leaving coil) is the air that is cooled to the final desired condition and supplied to the controlled space. As it is recirculated into the return duct, it becomes Return Air (RA) (air entering the coil). If the air is to be exhausted to offset the OA brought in, then the air exhausted is labeled as Exhaust Air (EA). If any of the air types are mixed in a mixing plenum, then the name given to the air following this process is Mixed Air (MA). All of these situations can be plotted.

REMINDER:

The analysis of air is a valuable tool for the specialist. Psychrometrics give him an understanding of what the mechanical cooling process must overcome to properly perform. In order to correctly determine the properties of air, the refrigeration specialist must be able to use the psychrometric chart.

Installation of Insulating Materials

A large number of insulating materials have been developed for buildings. In air conditioning, it is absolutely essential that the insulation is designed to reduce heat loss by conduction, convection and radiation. In addition, vapor barriers should be included in the insulation or in the walls to reduce moisture travel through the wall.

Insulation selected for installation should have sufficient strength to support itself and not shrink or settle. It must not deteriorate in the presence of moisture, and it must not have any unpleasant odor. The insulation should be vermin proof and fire resistant.

The type of insulation to use in a building depends, to some extent, on the method of application. For example, there is the bulk type and batt type application. Bulk type, easy flowing insulation can be blown into the space between the studs of a building already constructed. Batts, flexible insulations, are easy to install and they conform to any irregularities in the construction. Batts of rock wool and blankets of pulverized wood are examples of this practice.

Safety

Care should be taken when handling insulating materials to avoid exposure to skin, eyes, and intake into the lungs. Severe itching, eye and lung irritation could result.

YOU HAVE COMPLETED THE DIRECTED STUDY AND HOMEWORK ASSIGNMENT IN PREPARATION FOR DAY 36.

START HERE FOR DIRECTED STUDY TO BE COMPLETED PRIOR TO DAY 37.

Read paragraph 22-29, page 792, Modern Refrigeration and Air Conditioning and answer the following questions.

1. Solid particle air contaminants fall into what three groups?

2. What are the two most common liquid impurities found in the air?

Read paragraph 22-30/31, page 793/794, Modern Refrigeration, Air Conditioning text and answer the following questions.

1. What are adhesive filters made of?

2. What is a class 2 adhesive filter?

Read paragraph 22-32, page 794, Modern Refrigeration, Air Conditioning text and answer the following questions.

1. What does ionizing mean? _____

2. What are the three ways to ionize the air? _____

Read paragraph 22-35, page 797, Modern Refrigeration, Air Conditioning text and answer the following question.

Water does not remove what? _____

Read paragraph 22-37, page 798, Modern Refrigeration, Air Conditioning text and answer the following question.

What is the purpose of activated carbon filters? _____

Filters should be cleaned or replaced when they lose their efficiency or when they are so clogged that they produce too much pressure drop across the filter, a visual inspection is one way to determine if a filter needs replacing. When the pressure drop across the filter is more than 25 percent of the pressure drop across the fan, the filter should be changed.

Always replace filters with the arrows pointing in the direction of air flow. The side toward the blower has more adhesive and must be on the air-out side of the filter. If this is not done, the filter will quickly load with dirt and clog.

When replacing filters make these two checks:

1. Inspect filter for tears or holes. Place a strong light on one side of filter and look through filter from other side.
2. Use manometer to check pressure drop.

Fans

Air is moved by mechanical means in an air-conditioning system. The fan converts mechanical energy (fan blade rotation) into gas energy (airflow). This is accomplished by means of a wheel or blade, imparting a spin on the air so that it will leave the fan assembly in a forward motion to the point of destination.

Fans are classified into two major categories: AXIAL and CENTRIFUGAL.

Types of Fans

AXIAL FANS. These fans move air in a flow parallel to the shaft. The air will have a spiral motion, but will be moving in a parallel plane. Axial fans have three blade classifications.

Propeller Fan Blades. Propeller fan blades are found on the pedestal or table fan common to home use. Fans of the ceiling variety use propeller blades. These fans are used to move air within a given area (circulation). Normally, they have a safety shroud around them. They can be used only if a low volume of air movement is required and normally are used for exhaust or ventilation purposes. They can be direct drive or belt driven, see figure 14.



Figure 14. Propeller Fan

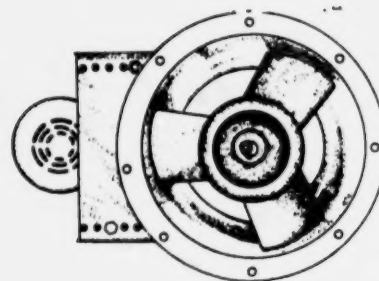


Figure 15. Tube-Axial Fan

Tube-Axial Fans. They are used for heavier duty air movement. They are built for mounting in ductwork whereas the propeller type is mounted in a wall. Since the air will move at a high velocity, the increase of the spiral movement will make greater duct pressure losses, and will increase the amount of noise in a duct system. For this reason they are normally used for industrial applications where noise is a small consideration, and space is of no concern. They are direct drive or belt driven. See figure 15.

Vane-Axial Fans. These fans are in reality nothing but a tube-axial fan with vanes installed in the fan housing. The vanes are used to straighten out the spiraling motion of the air. This offers the added factor of less noise and increased efficiency. (See figure 16.)

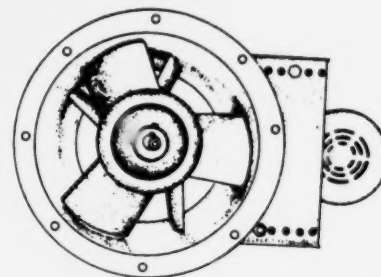


Figure 16. Vane-Axial Fans

CENTRIFUGAL FANS. They move the air into the blower housing parallel to the shaft but discharge it radially to the shaft (see figure 17). This means that the air is discharged at a 90° angle or plane from the shaft of the fan. The centrifugal fan consists of a wheel (sometimes called a squirrel cage) mounted horizontally on a shaft, which rotates within the housing. Air enters parallel to the axis through the fan housing. The air may enter at either one or both ends of the wheel. The centrifugal fan will operate with less noise, but consume more power under maximum air delivery when compared to an axial flow fan.



Figure 17. Fan Blades

Air-conditioning specialists often refer to centrifugal fans as blowers. There are some factors which will be used in the determination of the fan type to be used for a particular application. They include:

- * Unit size
- * Drive motor selected
- * Internal layout of the unit
- * Shape of the coil
- * Resistance of systems ducts

Fans are used to ventilate (induce fresh air), circulate the same air in a system, or to exhaust odor-laden air which is part of the ventilation-circulation process.

QUESTIONS

1. How is air moved in an air conditioning system? _____
2. What are the three types of axial fans? _____
3. What are the three types of centrifugal fans? _____
4. What is one disadvantage of the centrifugal fan? _____

Installation

Centrifugal fans are installed in air conditioning systems where there is duct work or other sources of static resistance, such as filters, because of their ability to handle air at high static pressures, with a minimum of noise and at high efficiency. Static pressure is the outward pressure of the air against the top, bottom, and sides of an air duct. It is the resistance of the duct to air flow. Axial flow fans are installed when an application calls for large air volumes at low static pressures.

QUESTION

What is static pressure? _____

When installing fans, there are some general guidelines that the air conditioning specialist should keep in mind. It was previously mentioned in this study guide that large fans should be installed in a location remote from the conditioned space to reduce noise. The electric motor driving the fan should be located outside of the duct for two reasons. First, the motor is more easily serviced, and second, if the motor were located inside the duct, the motor noise would travel through the duct system to the conditioned space.

When the fan and motor are set in place, and the motor is connected to the power source, assure the proper direction of rotation. If a three phase motor is turning in the wrong direction of rotation, simply swap any two of the three power leads.

QUESTION

1. Where should large fans be installed? _____
Why? _____
2. Where should the electric motor driving the fan be located? _____
Why? _____
3. After the fan motor is installed, and connected to power, what check should be made?

For best results, the spacing between the centers of the fan shaft, and the motor shaft, should not be less than the diameter of the largest pulley, and not greater than the combined diameters of both pulleys.

Servicing Fans

A rattle of a fan motor may sometimes be nothing more than a loose fan on a shaft. The noise can be remedied by tightening the set screw that fastens the fan hub to the shaft. Smaller fans have either a round shaft, or a flat spot milled on the shaft.

If the fan is abused, the blades may be forced out of position, and one or more blades may vibrate. The easiest repair is to replace the fan. Any attempt to rebalance the blades is difficult unless special static and dynamic balancers are available. If the fan blades touch the fan housing, the motor may be out of line or the shroud or housing may be bent. The contact spot is usually easily detected and remedied by moving the fan on the shaft or moving the shroud or housing. Do not try to bend the fan blades as this will cause the unit to vibrate.

QUESTION

1. What type of shafts do smaller fans have? _____
2. What is the easiest repair for fans which have been abused? _____
3. What could possibly be the trouble with fan blades that touch the housing? _____

On belt driven fans it is important that when a belt breaks, or is worn to the point at which it needs to be replaced, you should replace the whole set of belts, preferably with a matched set. Belt tension is important too. They should be adjusted so that they are not too tight (you should be able to depress the belts slightly) and not too loose as to cause slipping. Belts that are too tight cause overheating and excessive bearing wear, and may overload the fan motor. Loose belts will cause squealing due to slippage, and belt wear will be excessive.

1. What should the air conditioning specialist do when a belt in a multibelt set breaks? _____

2. Drive belts that are adjusted too tight could cause _____

3. What does belt squeal indicate? _____

Alignment

For efficient operation and reduced maintenance, alignment of belt driven fans must be considered. Alignment means adjusting the fan pulley and motor pulley so that they are in a straight line with each other. The fan and motor pulleys must be a close alignment to prevent excessive belt wear, and motor vibration. To check alignment, use a belt adjusting and aligning tool, or a straight edge.

1. What does alignment mean? _____

2. What can be used to check fan and motor alignment? _____

AIR FLOW INSTRUMENTS

One of the functions of an air conditioning system is to deliver the proper amount of air to an area at a specific time. It is the air conditioning specialist's job to know if the system is producing properly. There are several instruments on the market that will measure the velocity of the air. We will measure the velocity of the air using some of these instruments. There are two basic factors that determine the amount of airflow. The velocity or rate of air movement and the area that it must pass through. When talking about velocity, we use the terms "feet per minute (FPM)," and "cubic feet per minute (CFM)."

AIR MEASURING INSTRUMENTS

There are three types of instruments commonly used in the field. These are the anemometer, inclined manometer and velometer. All of these instruments are employed to measure the velocity in FPM of airflow. Readings can be taken at the following locations: Return air duct, supply air duct, outside air duct or inside the duct system.

QUESTIONS

1. What are the two basic factors to consider when determining the amount of airflow?

2. What are the three types of instruments commonly used in the field for measuring airflow?

Anemometer

The anemometer is an instrument used to measure air velocity in linear feet. This meter is composed of the fan housing, three dial faces and the propeller which moves at the rate of the air speed turning a gear mechanism which operates the dials. There is an engaging lever and a reset lever on top of the dial face.

In using the anemometer, we normally take readings at the duct face. To operate the anemometer, place the instrument into the stream of air being measured. Before starting, check to be sure that your hands are cupped around the meter in such a way to prevent obstructing the airflow through the meter. Allow the propeller to reach maximum speed, then trip the engaging lever and begin moving the meter slowly over the entire duct opening. The length of time that you take the reading should be determined prior to beginning, remembering that the longer the reading time the more accurate you will be.

In reading the anemometer, suppose you held the instrument in the airstream for two minutes. The readings on the dials would be read in the following sequence:

- ____ Left dial reading.
____ Right dial reading.
____ Center dial reading.

If the indicator on the two smaller dials is between any two numbers, take the reading of the lesser number and read the large dial exactly as indicated (see figure 18).

1. The anemometer measures air velocity in what? _____
2. Why should we cup our hands around the meter? _____
3. In what sequence are the dials read? _____

In figure 18, the left dial reading would be 8000, the right dial reading would be 300, and the center dial reading would be 80. Therefore, combining the numbers into proper sequence, the resulting anemometer reading would be 8380.

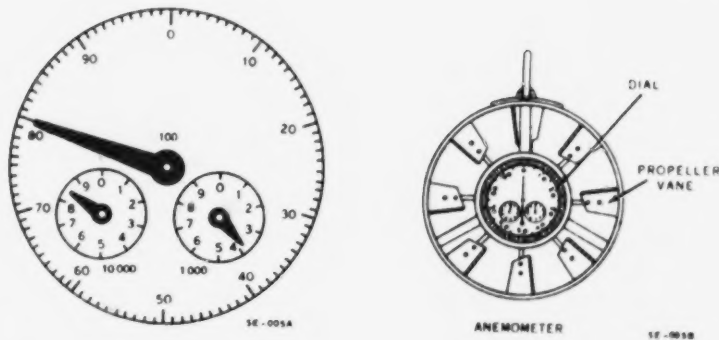


Figure 18. Anemometer Reading (AR)

The following formula is used to convert the anemometer reading to FPM velocity:

$$\begin{aligned} \text{AR} &= \text{ANEMOMETER READING} \\ \text{ET} &= \text{ELAPSED TIME} \\ \text{FPM} &= \frac{\text{AR}}{\text{ET}} \end{aligned}$$

To figure the FPM of our sample problem, the answer would be:

$$\text{FPM} = \frac{\text{AR}}{\text{ET}} \text{ or } \frac{8380}{120 \text{ (seconds)}} = \frac{8380}{2 \text{ (minutes)}} = 4190 \text{ FPM}$$

QUESTIONS

1. What does AR mean? _____
2. What is ET? _____
3. What is the formula used to find FPM using the anemometer? _____

Inclined Manometer

The manometer family of air measuring instruments contains various types and styles; however, we will limit the study of manometers to one type, the inclined manometer. The manometer is used to measure the pressure of air in inches of water. Within the duct system we find two predominant pressures, static and total. Static pressure is the outward pressure of air in all directions. Total pressure is the force exerted by the movement of air in the direction of flow. Often it is impossible to get the manometer into the airstream to measure the pressure, so the pitot tube was developed to allow access to the internal sections of the duct in hard to get to areas. In reality the pitot tube is a tube within a tube as indicated in figure 19.

QUESTION

What are the two pressures within the duct system? _____

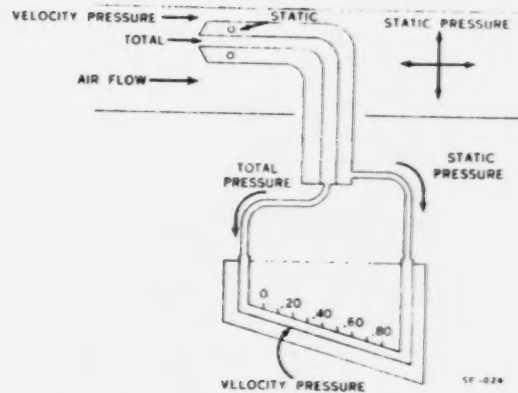


Figure 19. Pitot Tube and Manometer Installed

The pitot tube is inserted into the airstream and total pressure goes into the center of the assembly to the manometer, forcing the oil column in the meter downward. The static pressure enters the small ports surrounding the tube to the manometer forcing the column of oil in the meter tube upward. The velocity reading is taken on the adjustable scale where the oil level stabilizes.

QUESTION

Where does static pressure enter? _____

The pressure indicated on the manometer is known as pressure of velocity. It is represented as PV in the conversion formula used to convert pressure into feet per minute. To convert pressure of velocity into FPM, the following formulas will be applied:

$$FPM = \sqrt{PV} \times 4050$$

FPM -- the number of feet of air which will pass through a duct area in one minute.

$\sqrt{\quad}$ -- symbolizes square root.

PV -- pressure of velocity as read on the inclined manometer.

X -- multiplied by.

4050 -- is a constant and is based on the velocity of standard air.

Now, let's see how the formula works. Assume the velocity pressure reading of .25 has been obtained with the manometer.

$$FPM = \sqrt{.25} \times 4050 = .5 \times 4050 = 2025$$

QUESTIONS

1. What is PV? _____

2. What is the formula to find FPM when using the manometer? _____

3. Define feet per minute. _____

Velometer

The velometer is a rugged mechanical system, soundly engineered for very concise readings. Inside the meter, air impinges on an aluminum vane moving the pointer. This vane travels in a calibrated air chamber or tunnel constructed to be airtight to provide a desirable scale distribution. The moving system is balanced by counterweights to provide accuracy in all positions. The moving system is equipped with bronze hairsprings and moves on monel pivots which ride in sapphire jewel bearings. Some velometers are equipped with filters to protect them from extreme dust conditions. When a filter is supplied with the instrument, the filter is an integral part of the instrument and must be used. If the filter is left out, the instrument will give a false reading.

To measure velocities at supply openings, attach the proper jet by means of the appropriate tube and tube fittings. To determine the average velocity, mentally divide the opening into a number of equal areas. Take a reading at each of the areas and average the readings. There is no exact rule for the exact number of readings that must be taken, but the more that are taken, the more accurate the average, and it is recommended that a minimum of six readings be used.

To measure the air velocity at the suction opening, connect the proper jet by means of the tube and tube fittings to the right-hand port of the meter. While taking the readings, hold the jet so that it is perpendicular and the tip is in the same plane as the opening. This is very important because the velocity changes very fast in front of a suction opening. To measure velocities inside of ducts, use the duct jet called for in the manual of instructions. The duct jet should be inserted into the left-hand port.

Read the scale marked with the same number of jet being used.

This instrument is calibrated for use with air being measured at 68°F temperature. When the temperature of air is not 68°F use the following formula to compensate. Remember this instrument reads directly in FPM.

Formula: $\frac{460 + \text{temperature}}{460 + 68^\circ\text{F}} \times \text{velometer reading}$

QUESTION

With a velometer, air velocity is measured in what? _____

Calculating Cubic Feet per Minute (CFM)

After establishing the FPM, the CFM can be established using the formula:

$$\text{CFM} = \text{FPM} \times \text{DUCT AREA (SQUARE FEET)}$$

REMINDER:

Air velocity can be measured with an anemometer, manometer or velometer. After velocity is known, it is a simple matter to determine the CFM.

BALANCING AIR-CONDITIONING SYSTEMS

Air-conditioning systems are designed to condition the air within the system and then to distribute this treated air to the proper place, in the proper amounts, and with the least possible annoyance to the consumer of the conditioned air.

Use of Air

In air-conditioning practice, as air is passed through the unit, it is heated or cooled, humidified or dehumidified, cleaned, and then distributed to places where it is needed. An air-conditioning unit, regardless of its efficiency, and its size, would be handicapped if the air could not be properly distributed. It is important that the air distribution be accurately proportioned to the need and adapted to the apparatus in which it is to be used. The distributed air must be clean, provide the proper amount of ventilation, and must carry enough heat to keep the conditioned space warm or must be able to absorb enough heat to cool the conditioned spaces.

Stratification of Air

Air in an occupied space must be kept moving, or stagnation or stratification results. Warm air tends to rise, cold air tends to settle. In a room where the air is not deliberately moved, the air will assume levels according to temperature.

It is important to locate all automatic thermostats and humidistats at the proper level because of this stratification. Also, stratification tends to make smoke haze hover in layers.

Unfortunately, some grilles are so located that the air will be moved only in certain parts of the room and the air will become stagnant in other parts of the room. There is also the problem of the obstruction to the air movement caused by the furnishings of the room. For this reason, and to enable higher grille velocities, some grilles are located high in the room (6 feet or more), and some are located in the ceilings. These high grille locations necessitate that the grilles be attractive in appearance or concealed. This is called a diffusion grill because its design promotes mixing of some of the room air with the entering air.

Air Ducts

To deliver air to the conditioned space, air carriers are needed. These carriers are called ducts. The ducts are made of sheet metal or some noncombustible structural material.

The ducts work on the principle of air pressure difference. If a pressure difference exists, air will move from the higher pressure to the area of lower pressure. The greater the pressure difference, the faster the air will flow.

Two shapes of ducts commonly used for carrying air are: (1) round duct, (2) square or rectangular duct. The round duct is the more efficient based on volume of air handled per perimeter distance (distance around). That is, less duct material is needed to make a large enough duct to carry the necessary air.

QUESTIONS

1. What happens to air if it is not kept moving? _____

2. What are two shapes of ducts commonly used? _____

The square or rectangular duct harmonizes with building construction and fits into walls and ceilings better than round ducts. It is easier to install rectangular ducts between joists and studs.

Duct Sizes

To determine the size duct that should be used to carry air to a room, it is necessary to first find the volume of air that is to be delivered to the room.

This volume of air depends on the amount of heat the air must deliver to the room during the heating season, or the amount of heat to be removed during the cooling season.

Determining Air Quantities

To determine the proper air quantities to each room there are certain things that must be known:

1. Specific heat of air
2. Weight of air
3. Temperature difference between supply and room temperature
4. Total Btus of the conditioned space

The specific heat of air is the amount of heat required or released to change the temperature of one pound of air 1°F. The specific heat of air is .24 Btus/Lb/Deg F.

The weight of air is derived from the definition of standard air, which is one pound of dry air at 70°F, which occupies 13.34 cubic feet, one cubic foot has a specific density (weight) of .075 at atmospheric pressure of 14.7 psia or 0 gage, at sea level.

Now that we know what the specific heat of air and the specific density or weight of standard air is, we can compute the CFM required for each room by using the formula:

$$CFM = \frac{\text{Room Heat Load (Btus/HR)}}{1.08 \times TD}$$

Room load will be found during heat load estimating normally done by engineers. The temperature difference (TD) would depend on the design conditions. The 1.08 is derived from multiplying the weight of one cubic foot of standard air (.075) times the specific heat of air (.24). This will give you the amount of heat the air is capable of absorbing in one minute. We then multiply this times the number of minutes in one hour (60), which gives us our 1.08, the heat absorbing capability of air in one hour. Then by multiplying times our design temperature difference then dividing into our room load will give us our Cubic Feet Per Minute (CFM) required to maintain desired room temperatures.

QUESTIONS

1. What must be known to determine the proper air quantities to each room? _____

2. What is the formula for computing the CFM required for each room? _____

Now that you know something concerning the air distribution system, all that remains is to balance the system. Easier said than done, but this could become a long and tedious process. By using the formula for determining room air volume, you can then start with the room that has the highest heat load. Start with that room and work your way to the room with the lowest heat load. This process may require repeating more than one, two, three or more times. Remember, once you change the air flow in one room, this will affect the air flow in another room. Continue the process until the required CFM per room is reached.

QUESTIONS

1. Which room do you start with to adjust the CFM air in each room? _____

2. How many times is this process repeated? _____

3. What will be the affect of airflow in one room if the airflow in another room is changed? _____

You have completed the directed study in preparation for Day 37. Read the following paragraphs and be prepared to discuss the information tomorrow in class.

There is a definite need for supplying fresh air where natural ventilation is insufficient; to remove heat, vapors, or fumes from a building or process and discharge it into the atomsphere; to collect and remove dust; and to circulate air, providing "comfort" to individuals. You will be responsible for maintaining these systems which supply this fresh air.

The biggest problem in these systems is excessive leakage in air ducts. This happens most often when ducts fall off of supply air plenums, main trunk lines, or duct outlets.

Inspect ducts periodically for the following conditions: deformation; leakage losses caused by loose clean-out doors, broken joints, holes worn in ducts (most frequently in elbows), and poor connections to fans; and accumulations of material, such as dirt, lint, and condensation of oil or water vapor, on the interior of ducts. Repair or replace defective ducts or duct connections. Clean ducts annually.

YOU HAVE COMPLETED THE DIRECTED STUDY AND HOMEWORK ASSIGNMENT IN PREPARATION FOR DAY 37.

WATER PUMPS

OBJECTIVE

To familiarize you with basic facts about centrifugal water pumps, their installation, operation and maintenance. Also, to provide you with basic facts related to cross-connection/back flow prevention.

INTRODUCTION

The installation and maintenance of centrifugal pumps are your responsibilities. To properly maintain an enclosed chilled water system, one must be able to service the centrifugal pump. The pump moves the chilled water through the system. You will also be called upon to service the centrifugal pumps used to circulate water in a cooling tower condensing system.

Complete directed study, Engineered Performance Standards (pamphlet will be furnished by your instructor) and be ready to pass a written criterion on this material on Day 38.

Then begin here for homework study to be completed prior to Day 38.

Centrifugal Pumps

Centrifugal pumps may be either single- or double-suction. In the single-suction pump, the water enters from one side of the impeller only. In the double-suction type, the water enters the impeller from both sides. Centrifugal pumps may also be classified as single or multiple stage. By staging, we mean the number of impellers the water must go through before it goes to the outlet of the pump. In a three-stage pump, the first impeller would pick up the water, put it in motion and discharge it to the inlet of the second impeller. The second impeller adds more motion to the water and passes it along to the third impeller. The third impeller adds more motion to the water and discharges it to the outlet of the pump. By using three or more stages, it is possible to lift water 100 feet or more.

QUESTION

1. Where does the water enter the double-suction type centrifugal water pump? _____

2. How high can water be lifted using the three stage centrifugal water pump? _____

3. What does staging mean? _____

Most centrifugal pumps used in refrigeration work are of the single-suction, single-stage type.

Principle of Operation

The centrifugal pump utilizes the throwing force of a rapidly revolving impeller. The liquid is pulled in at the center of the impeller and is discharged at the outer rim of the impeller. By the time the liquid reaches the outer rim of the impeller, it has acquired a considerable velocity. The liquid is then slowed down by being led through a volute (a gradually widening channel in the pump casing). See figure 20. As the velocity decreases, the pressure increases. It is this pressure which enables the pump to move the liquid.

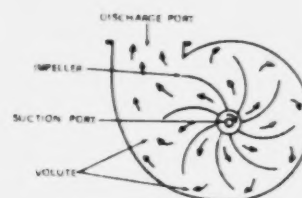


Figure 20. Simple Centrifugal Pump

QUESTIONS

1. How is the water or liquid brought in and discharged in the centrifugal pump operation? _____

2. What is a volute? _____

Maintenance of Centrifugal Pumps

Never run a centrifugal pump dry, because liquid is necessary to lubricate the internal surfaces. Never throttle the pump suction to regulate the flow of water, because cavitation will result. Do not permit the pump to stand idle for long periods of time. It should be operated at least once a week. The following paragraphs discuss preventive maintenance inspection and pump maintenance requirements pertinent to centrifugal pumps.

DAILY REQUIREMENTS. Each day, you should inspect the centrifugal pump for abnormal noise and vibration; abnormal pressure and flow conditions; excessive or inadequate packing leakage (water-cooled bearing); hot bearings; and hot stuffing box.

SEMIANNUAL REQUIREMENTS. Every six months, you should check alignment of the pump and driver with the unit at a standstill and normal operating temperature; check shaft sleeves for scoring; replace packing by cutting the packing diagonally and stagger pieces installed around the shaft, if required; drain the oil from oil-lubricated bearings. Do not overgrease the bearings. When adding grease, remove the drain plug or use a safety fitting to prevent overgreasing.

ANNUAL REQUIREMENTS. On a yearly basis, the pump is dismantled, a complete inspection is performed, and the following requirements are satisfied. Check the wearing ring clearances according to the manufacturer's instructions; diametral clearance between 0.005 and 0.025 inch is usual. Examine bearings for wear, check clearances according to manufacturer's instructions, and overhaul, if necessary. Check shaft for scoring, corrosion, or wear at the seals, and also for proper alignment. Check impellers for corrosion, erosion, or excessive wear. Check and calibrate pressure gages, thermometers, and flowmeters. Inspect suction and discharge strainers.

QUESTIONS

1. Why should you never run a centrifugal pump dry? _____

2. What should be done when adding grease? _____

3. What should impellers be checked for? _____

Installation

A concrete foundation must be laid before a centrifugal pump can be installed. Figure 21 shows the concrete foundation that is necessary to provide a strong enough base to withstand pump vibration and maintain alignment of the pump and motor. A one-inch clearance should be left between the foundation and the pump base. This is done to allow movement of the bolts and to align the pump and the motor. A washer is placed between the head of the bolt and the pipe to hold the bolt in place. The bolts should be long enough to stick up through the nut after the pump has been installed. Wedges are placed near the center of the motor and pump, sometimes near the middle of the bedplate. The wedges provide for the leveling of the bedplate and proper clearance for grouting.

QUESTIONS

1. Why must the concrete foundation be strong? _____

2. What should the clearance be between the foundation and the pump base? _____

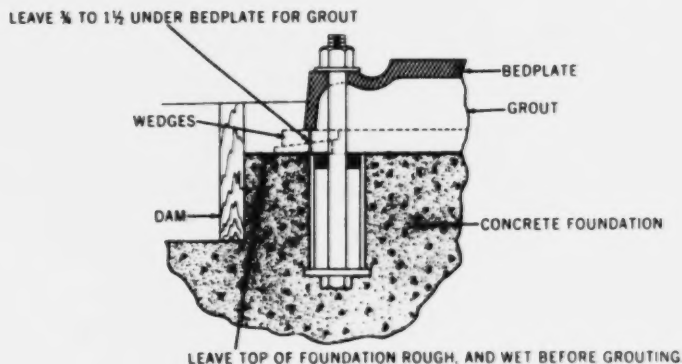


Figure 21. Pump Foundation

Tighten the foundation bolts evenly and finger-tight after the wedges have been adjusted. Be sure the bedplate is still level. Final tightening of the foundation bolts is made after the grout has set for 48 hours.

Removal

The pump and motor assembly may be removed after removing the nuts from the foundation bolts. Lift the assembly from the bedplate. If only the motor or pump is to be removed, unfasten the hold-down bolts on either one. Disconnect the coupling and lift the unit out.

QUESTION

How long should grout be allowed to set before final tightening is accomplished? _____

INSTALLATION OF THE FLEXIBLE COUPLING

Steelflex Coupling

The coupling comes in two pieces. They are referred to as halves. Remove the motor hold-down bolts and slide the motor back to increase the distance between the motor and the pump shafts. Slide one of the halves on the pump shaft and the other on the motor shaft. The slot key is used to position the two halves. Tighten the setscrews to hold the halves in place. The halves are pushed together by remounting the motor. Press the steelflex spring into place around the coupling halves as shown in Figure 22. The coupling cover comes in two pieces. Install the halves in the rubber retainers and bolt them together.

Spider Insert type Coupling

Before installing this coupling, the motor hold-down bolts should be removed and the motor pushed back to make enough clearance to install the coupling halves, one of each shaft. The halves may be secured on the shafts by setscrews. A rubber grommet is placed between the halves as the motor is being installed and the halves are being pulled together.

QUESTIONS

1. What are two types of couplings? _____

2. How are the halves secured on the shafts using the spider insert type coupling? _____

3. On the steel flex coupling, what is used to position the two halves? _____

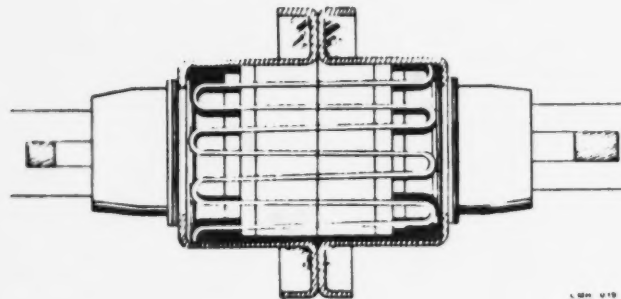


Figure 22. Steelflex Coupling

The motor and pump halves can be brought into alignment by adjusting the wedges and tightening the pump and motor hold-down bolts. Check the gap and angular alignment on the coupling. The coupling shown in figure 23 is the "spider insert" type. The normal gap is one-sixteenth of an inch. The gap is the difference in the space between the coupling halves and the thickness of the spider insert. Angular alignment, a bend in the coupling, may be checked by using calipers at four points on the outer ends of the coupling hubs, at 90° intervals as shown in figure 23.

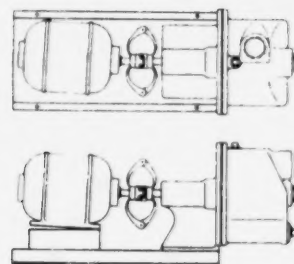


Figure 23. Checking Angular Alignment

When the measurements show the ends of the coupling hubs to be the same distance apart at all four points, the unit will be in angular alignment. The motor hold-down bolts are loosened and the motor shifted or shimmed to obtain gap and angular alignment. The bolts are tightened down after the adjustments have been made.

Alignment of the pump and motor through the flexible coupling is very important for trouble-free mechanical operation. The following steps must be followed to start alignment of pumping unit:

- Tighten the foundation bolts.
- Tighten the pump and motor hold-down bolts.
- Check the gap and angular adjustment.

QUESTIONS

1. How is the gap determined? _____
2. What is the normal gap? _____

Stuffing Boxes and Packing

In repacking be sure that sufficient packing is placed back of the lantern ring so that the liquid for sealing is brought in at the lantern ring and not at the packing (figure 24).

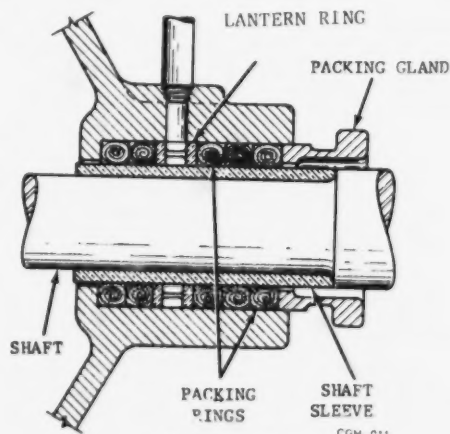


Figure 24

The piping supplying the sealing liquid should be fitted tightly so that no air enters. On suction lifts, a small quantity of air entering the pump at this point may result in loss of suction.

If the liquid pumped is dirty, gritty, or is acidic; sealing liquid should be piped to the stuffing boxes from a clean outside source of supply in order to prevent damage to the packing and shaft sleeve.

Packing should not be pressed too tight, as this may result in burning the packing and scoring the shaft sleeve. A stuffing box is not properly packed if friction in the box is so great that the rotor cannot be turned by hand.

Always remove and replace all of the old packing. Do not re-use some of the old rings because they "look" all right. If, for instance, the outermost accessible rings only are replaced, then they will be the only rings compressed when the gland is tightened. Consequently, the new rings will have to do all the work of sealing the box and accelerated packing will result. The old rings, having been previously compressed, will move as a unit and fail to provide any sealing effect.

To remove packing, a puller, as illustrated in figure 25, can be used. It consists of a short corkscrew section, on the end of a piece of flexible wire, attached to a handle. If the packing should break up while being pulled out, all the broken pieces should be removed so as to have a clean and clear box before inserting the new packing. A small piece left in the box will make it impossible to repack the pump properly.

QUESTION

Why must all of the old packing be removed? _____

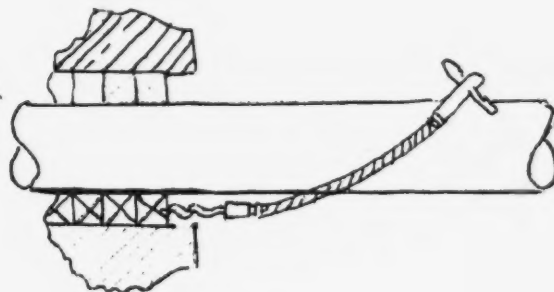


Figure 25

If the new packing is slightly large, never attempt to flatten it with a hammer. Place the packing on a clean flat surface and roll it with a piece of pipe until the thickness is such that a slight effort is required to push it into the box.

When placing a ring over the shaft, do not pull the ends apart. Twist it over the shaft as shown in figure 26.

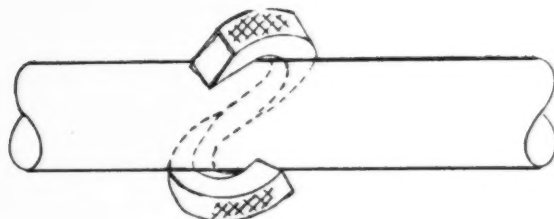


Figure 26

The rings should be tapped individually into place. Preferably, this may be done with a dummy gland which can be a split sleeve of metal or wood which fits over the shaft. The outside diameter should be slightly smaller than that of the stuffing box bore. The last few rings may be pushed into place using the packing gland.

The packing ring joints should be staggered as each ring is installed (180° apart for two rings, 90° apart for three rings, etc.).

The lantern ring must be installed so that when the packing is compressed it lines up with the cooling liquid opening. Note: When unpacking the box, the arrangement of the gland, the number of packing rings behind and in front of the lantern ring, and repack in the same arrangement.

When the box is fully packed and the last ring has been firmly tightened with the gland, rotate the shaft a few times by hand to "Glaze" the packing. Then back off the gland nuts and retighten finger-tight only. This allows the packing to expand as it warms up.

Important. Many pump failures occur because inexperienced maintenance personnel observe liquid dripping from a gland and endeavor to stop it by tightening the gland bolts. For a very short period the leakage is stopped. The packing then becomes overheated and burns or scores the shaft sleeve and the pump must be shut down.

A fundamental requirement of all packings is that they be lubricated at all times and this requires constant leakage. When the gland is properly adjusted and the packing has been "run in," only a few drops of leakage a minute are necessary, but it is essential. Three to six drops is desirable.

QUESTION

What causes overheating of packing and burns or scores on the shaft sleeve? _____

Care must be exercised in tightening the gland so that it remains square to the shaft sleeve. This is done by tightening the gland bolts alternately only a slight amount at a time.

If this is not done, shaft sleeves may be scored by contact with the inner edge of the gland bore, and the scored area could lead to rapid packing failure.

Water Pump Operation

Your duties may require you to check pumps for correct operation. The following listed items will be helpful to determine the proper operation.

Check for:

- o Proper pump rotation
- o Correct pump water pressure (See manufacturer's specification)
- o Excessive motor and bearing temperatures
- o Excessive vibration due to loose mounts
- o Sealed suction intake
- o Proper drip from packing (3-6 drops per minute)

PUMP DISASSEMBLY/REASSEMBLY

Single Suction Pumps. Refer to figure 27.

1. See coupling manual for coupling disassembly.
2. Drain suction and discharge lines and pump casing.
3. Remove suction and discharge piping from pump flanges.
4. Remove bolts and dowel pins from pump feet. Pump may now be removed from base-plate for bench work if so desired.
5. Remove cap screws holding suction cover (Part 9) to casing (Part 1) and pull suction cover straight out to remove. If suction cover cannot be removed by hand, screw in the two square head jack screws in the suction cover flange.
6. Screw out impeller screw (26). Remove impeller washer (69), impeller (2) and impeller key (32).
7. Remove packing gland nuts and packing gland (17). Packing gland is split type and can be removed from shaft. Pull out front packing (13)--see STUFFING BOXES AND PACKING--and slide lantern ring (29) back against deflector (38). Remove balance of packing.
8. Remove cap screws holding casing (1) to bearing base (19). Casing is now free to be removed. Take care not to score shaft sleeve (14) when casing is taken off.
9. Slip shaft sleeve (14), lantern ring (29), deflector (40) and shaft sleeve gasket (38) from shaft.
10. Remove cap screws from bearing cover--inboard (35 and bearing cover--outboard (37). Remove bearing covers.
11. Shaft (6) and ball bearings (16 & 18) may now be PULLED (or PUSHED) from bearing base (19) in either direction. DO NOT HAMMER SHAFT AND BEARINGS FROM BEARING BASE. If difficulty is encountered in removal, use an arbor press or similar equipment to obtain larger forces. BEAR ON OUTER RACE ONLY!
12. If bearings do not slip off shaft after removal from bearing base, use same precautions for removal as mentioned above. BEAR ON INNER RACE ONLY!
13. Wrap bearings immediately in clean waxed paper or clean lint-free rags.

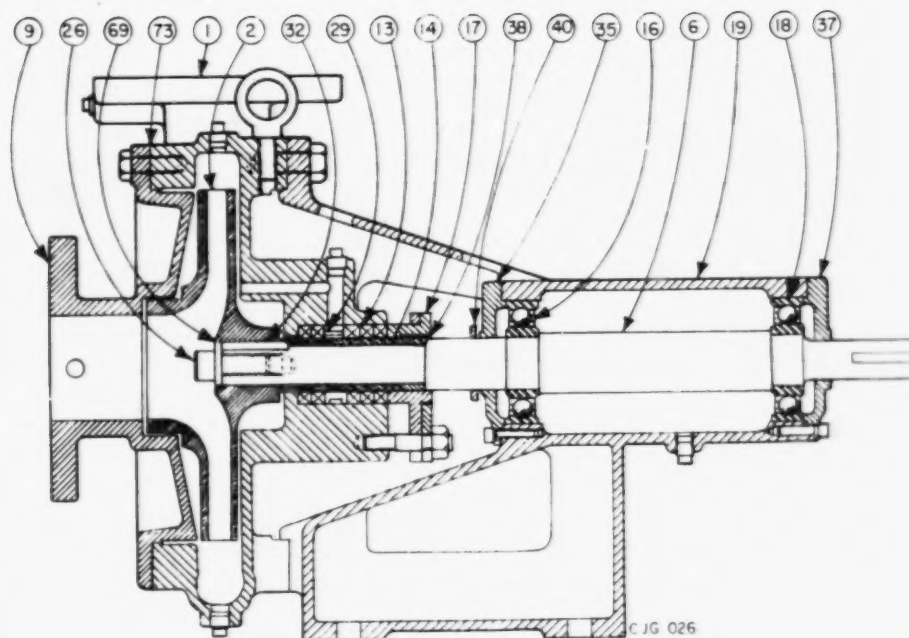


Figure 27. Single Suction Centrifugal Pump

1	Casing	26	Impeller Screw*
2	Impeller	29	Lantern Ring*
6	Shaft*	32	Impeller Key*
9	Suction Cover	35	Bearing Cover Inboard*
13	Packing*	37	Bearing Cover Outboard*
16	Bearing-Inboard*	38	Shaft Sleeve Gasket*
17	Packing Gland*	40	Deflector*
18	Bearing-Outboard*	69	Lockwasher*
19	Bearing Base*	73	Casing Gasket

*Indicated interchangeability among single suction pumps.

ASSEMBLY PROCEDURE

Single Suction Pumps. The assembly procedure is directly reversed from the disassembly procedure, with the following precautions:

1. The ball bearings should be given an ample coating of grease or oil just prior to assembly.
2. Push the bearings onto the shaft, pushing against the inner raceway. Do not hammer on the bearings!
3. For best service, use new gaskets (38 & 73). To prevent casing gasket (73) from sticking to flanges, coat flanges with mixture of flake graphite and motor oil.
4. Draw flange bolts up slowly and evenly.
5. Follow directions in STUFFING BOXES AND PACKING when repacking pump.
6. Check coupling alignment carefully. See COUPLING ALIGNMENT.

Since pumps are subject to malfunction, it is necessary to be familiar with the commonly encountered types of pumps and to be able to perform maintenance on them.

You have completed the first part of directed study in preparation for Day 38. Read the following paragraphs and be prepared to discuss the information tomorrow in class. Directed study continued on page 4-1.

Cross-connection Control Terms.

Understanding various terms and their usage, as related to cross-connection control, is basic to the understanding of the program and the health of personnel using Air force facilities and water systems.

AIR GAP (AG) SEPARATION. The unobstructed vertical distance through the free atmosphere, between the lowest opening from any pipe or faucet supplying water to a tank, plumbing fixture, or other device at the flood level rim of the receptacle. An approved air gap separation must be at least double the diameter of the supply pipe, measured vertically above the top rim of the vessel--in no case less than 1 inch.

APPROVED SOURCE. "Approved," as used herein in reference to a water supply, means a water supply that meets those quality criteria stated in AFR 161-44, or that meets the State criteria if more stringent.

AUXILIARY SUPPLY. Any source or system other than the primary potable water supply that must be available in the building or on the premises.

BACKFLOW. The flow of water or other liquids, mixtures, or substances into distributing pipes of a potable supply of water from one or more sources, other than the intended source.

BACKFLOW PREVENTER. A device or means to prevent backflow.

BACKPRESSURE. A positive pressure placed on any downstream component of a system relative to any upstream component.

BACKSIPHONAGE. Backflow resulting from negative pressure in the distributing pipe of a water system.

CERTIFICATION. The program to identify the training and minimum level necessary for proper inspecting, testing, monitoring, maintaining, and repairing of backflow devices.

CONTAMINATION. Food and/or water made unfit for consumption by humans or animals because of the presence of environmental chemicals, radioactive elements, bacteria or organisms, the by product of the growth of bacteria or organisms, and the decomposing material (to include the food substance itself) or waste in the food or water.

CROSS-CONNECTION. A connection or arrangement of piping or appurtenances through which a backflow could occur.

DOUBLE CHECK (DC) VALVE ASSEMBLY. An assembly composed of two single independently acting check valves, including positive shutoff valves located at each end of the assembly and suitable connections for testing the water tightness of each check valve.

DRAIN. Any pipe that carries waste water or water bearing waste in a building drainage system.

EXTERNAL PROTECTION. A backflow preventer installed on a water service supply line to a building.

FLOOD LEVEL RIM. The edge of the receptacle or lowest level from which water overflows.

HEALTH HAZARD. Any condition, including faulty operating conditions, devices, or water treatment practices, that may have or create undesirable effects on the user's health.

HYDROPNEUMATIC TANK. The pressure vessel in which air pressure acts upon the surface of the water contained within the vessel, pressurizing the water distribution piping connected to the vessel.

INTERNAL PROTECTION. A backflow preventer installed on equipment water service line within the building.

OUTLET. The open end of a water supply pipe from which the water is discharged into the plumbing fixture.

PLUMBING FIXTURE. An installed receptacle, device, or appliance supplied with water or that receives or discharges liquids or liquid-borne wastes.

PLUMBING SYSTEM. Includes the water supply and distribution pipes; plumbing fixtures and traps; soil waste and vent pipes; building drains and building sewers, including their respective connection devices and appurtenances; and water treating or water using equipment.

POLLUTION. The addition of sewage, industrial waste, or other harmful or objectionable material to water. A general term that does not necessarily signify the presence of disease-producing bacteria.

POTABLE WATER. Water from any source that has been investigated by the health jurisdiction and that has been approved for human consumption.

REDUCED PRESSURE (RP) PRINCIPLE BACKFLOW PREVENTER. An assembly of differential valves and check valves, including an automatically opened spillage port to the atmosphere, designed to prevent backflow.

SANITARY DEFECTS. Conditions that may permit the contamination of a water supply during or after treatment. Examples include connections to water supplies that are not safe, low water by-passes in treatment plants, plumbing fixtures that are not properly designed and installed, or leaking water and sewer pipes in the same trench.

SUBMERGED WATER PIPES. A water pipe or extension thereto from a public water supply terminating in a tank, vessel, fixture, or appliance that may contain water of questionable quality, waste or other contaminant, or that is unprotected against backflow.

SURGE TANK. The receiving, nonpressure vessel forming part of the air gap separation between a potable water supply and an auxiliary supply.

VACUUM. Any pressure less than that exerted by the atmosphere.

VACUUM BREAKER (ATMOSPHERIC) (AVB). A vacuum breaker designed so as not to be subjected to static line pressure.

VACUUM BREAKER (PRESSURE TYPE) (PVB). A vacuum breaker designed to operate under conditions of static line pressure.

Approved Devices

GENERAL INFORMATION. All backflow prevention devices and assemblies used on Air Force installations must be devices that have been tested and approved by the National Foundation for Cross-Connection Control and Hydraulic Research, University of Southern California. The air gap is a device that is an exception to this list; however, all air gap installations must be as stated within this manual.

Approved Applications

CLASSES OF BACKFLOW DEVICES: Approved backflow devices must be installed based on the degree of the hazard. These hazards are divided into three classes, which are defined below:

Class I--Low Degree of Hazard. If a backflow were to occur, the resulting health significance would be limited to minor changes in the esthetic quality, such as taste, odor, or color. The foreign substance must be nontoxic and nonbacterial in nature, with no significant health effect.

Class II--Moderate Degree of Hazard. If backflow were to occur, the resulting effect on the water supply would be significant changes in esthetic qualities. The foreign substance must be nontoxic to humans.

Class III--High Degree of Hazard. If a backflow were to occur, the resulting effect on the water supply could cause illness or death if consumed by humans. The foreign substance may be toxic to humans either from a chemical, bacteriological, or radiological standpoint. Effects of these contaminants may result from short- or long-term exposure.

Devices that protect the potable water supply from these hazards are listed in figure 2-28. The terms contamination, pollution, backpressure, and backsiphonage are explained in earlier paragraphs.

<u>Degree of Hazard</u>	<u>Allowed Approved Devices</u>
Class I	Air Gap Atmospheric Type Vacuum Breaker Pressure Type Vacuum Breaker Double Check Valve Assembly Reduced Pressure Principle Device
Class II	Air Gap Double Check Valve Assembly Reduced Pressure Principle Device
Class III	Air Gap Reduced Pressure Principle Device

Air Gap. An approved air gap may be used under any and all conditions of hazard and pressure conditions.

Vacuum Breakers. Pressure and atmospheric vacuum breakers are primarily in-plant or end-of-service line solutions to a cross connection. They are not used in water service connections. They are placed at the end of a line, and at fixtures or equipment that discharge to atmospheric pressure. These do not protect against backpressure, only against backsiphonage. There must be no valve downstream from an atmospheric type vacuum breaker.

Reduced Pressure Principle Device. This device protects against both backpressure and backsiphonage and can be used for any degree of hazard.

Double Check Valve Assembly. This device works in a backpressure or backsiphonage mode. This device neither discharges water, nor does it provide a visual sign of backflow or unit malfunction. Therefore, it does not offer the degree of protection provided by the reduced pressure principle device.

Figure 28. Allowable Devices

Installation Practices

GENERAL INFORMATION. The selection of proper devices is very important. However, having the proper device on the connection is not sufficient; the device must be installed correctly.

Before installing any device, the pipeline should be thoroughly flushed to remove any foreign material.

If the approved device does not have shutoff valves, valves should be installed on each side of the device, so the device can be maintained and tested. A 1/4-inch test cock must be installed on the inlet side of the inlet shutoff valve.

Devices must be installed according to manufacturer's instructions.

Devices must be installed in an accessible location, with ample clearance to aid in testing and maintaining the device.

Discharge from reduced pressure principle devices' relief valve must not be into sumps, drains, etc. The minimum clearance above floors or grade is needed to insure an air gap between the relief valve and any water that might puddle beneath the device. The maximum height is needed so that the device can be easily maintained and tested. Devices should be protected from freezing in a protective insulated enclosure or installed within the building. In extremely cold areas, some form of heat should be provided within the enclosure.

REDUCED PRESSURE (RP) PRINCIPLE DEVICES. Figure 29 shows the proper installation of an RP device on a building service connection. The RP device can also be used for internal protection.

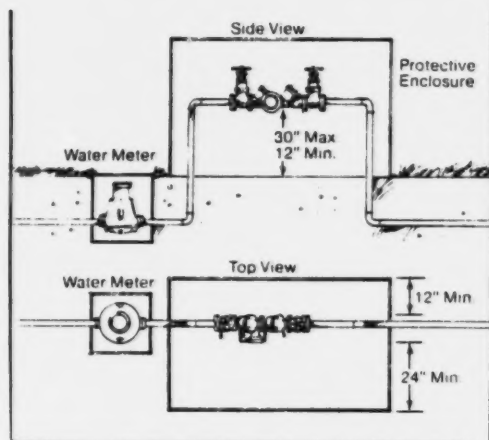


Figure 29. Installation of a Reduced Pressure Principle Device

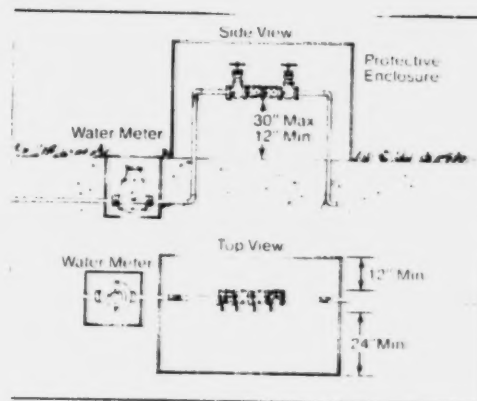


Figure 30. Double Check Valve

DOUBLE CHECK VALVE. Figure 30 reflects a typical installation of a double check valve on a service connection. This device can also be used for internal protection as well. Minimum and maximum distances are the same as that for the RP device.

PRESSURE VACUUM BREAKER (PVB). The pressure vacuum breaker cannot be installed where there can be backpressure, only where there can be backsiphonage. The pressure vacuum breaker can have shutoff valves downstream of the device. The pressure vacuum breaker must be installed at least 12 inches above the highest outlet or, if it is feeding an open tank, at least 12 inches above the highest overflow rim of the tank. Figure 31 reflects a typical installation on a lawn sprinkler system.

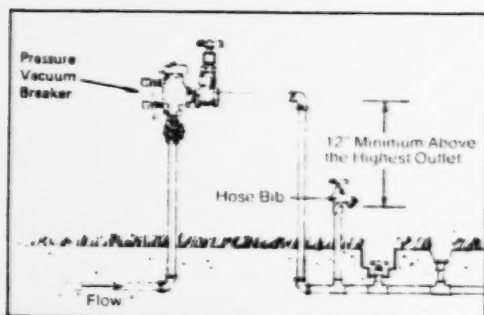


Figure 31. Pressure Vacuum Breaker

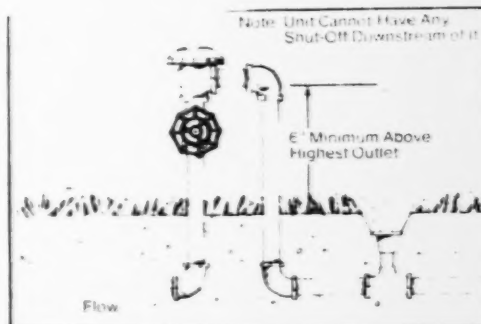


Figure 32. Atmospheric Vacuum Breaker.

ATMOSPHERIC VACUUM BREAKER (AVB). Just as the pressure vacuum breaker, the atmospheric vacuum breaker cannot be installed where there can be backpressure, only where there is backsiphonage. The AVB cannot have any shutoff valves downstream of it. It must be installed at least 6 inches above the highest outlet or the topmost overflow rim of a nonpressure tank. Figure 32 reflects a typical installation on a sprinkler system.

AIR GAP. An air gap shown in figure 33 is the physical separation of a potable water system supply line and the flood rim of an open receiving tank. The gap must be at least two times the diameter of the supply pipe, but not less than 1 inch.

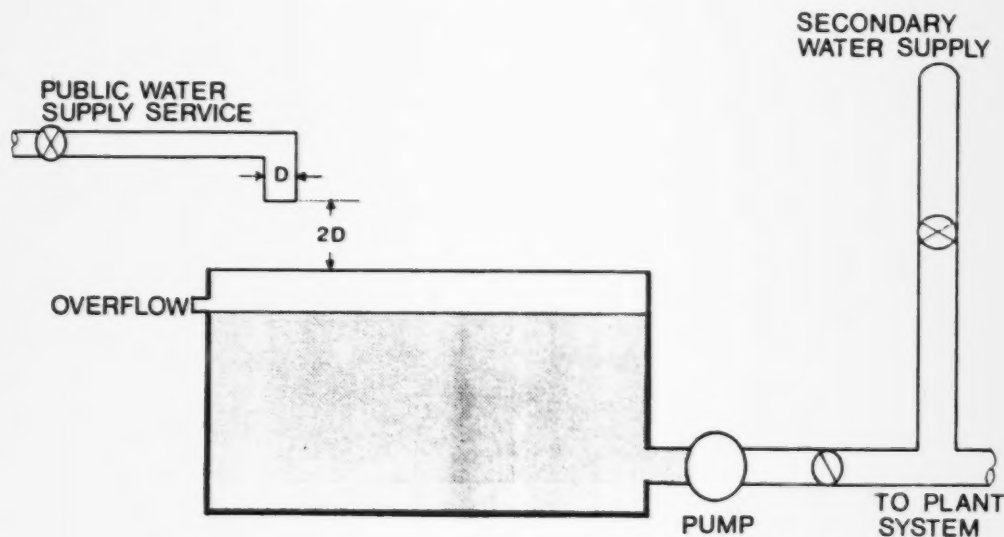


Figure 33. Safe Air Gap--Ground Level Tank

BATTERY PARALLEL INSTALLATION. Critical potable water supplies should have parallel installation of the proper approved backflow prevention device. Figure 34 reflects the installation of parallel, reduced pressure principle prevention. This avoids interruption to the water service when maintenance or testing is required. This type installation also provides a higher flow capacity than provided by one backflow preventer.

Typical Cross Connections

GENERAL INFORMATION. Cross connections are possible in all buildings where fixtures, devices, and equipment are connected to the potable water supply. In this section, some typical cross connections are described; however, there are many circumstances particular to Air Force operations that lend themselves to this potential hazard, which are not covered.

SPRAY HOSE IN SINK. This type of cross connection is commonly found in hospitals, kitchens, and janitor closets. A hose or tube is connected to the faucet on the sink (figure 35). When the faucet is left running, a loss of pressure of the supply main can siphon this used fluid back into the potable water system.

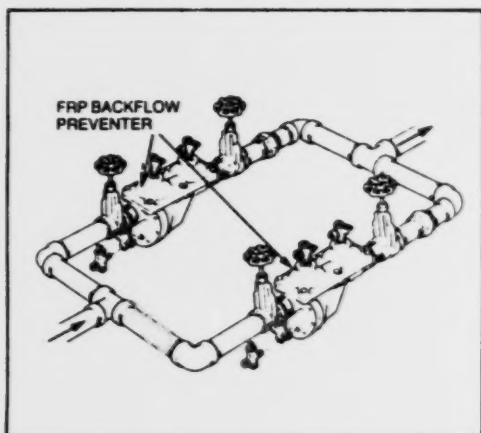


Figure 34. Parallel Installation

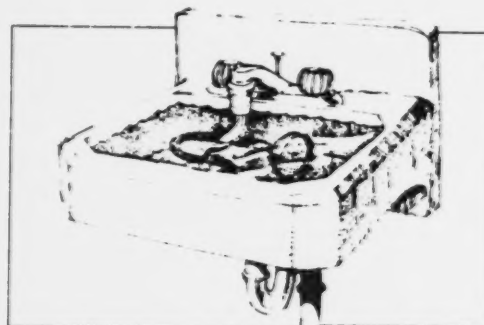


Figure 35. Spray Hose in Sink

SUBMERGED INLETS. At many Air Force installations that use chemically treated baths, the makeup water line runs directly into the tank (figure 36.) If there is backsiphonage, toxic chemicals can be sucked back into the potable water system.

HOSE BIBS. A hose bib seems innocuous, but it is those things that people do with the hose that create problems. In figure 37, a man is trying to blow a stoppage out of a sewer line, but with a sudden drop in the line pressure, this contaminated water can be back siphoned into the potable water system.

LAWN SPRINKLER. On a large number of lawn sprinkler installations, the sprinkler head is below the ground surface (figure 30). Water that may have been in contact with fertilizers and weed killers can then be backsiphoned through a leaky valve into the potable water system.

The need for cross-connection control may exist anywhere, whether industrial or residential. Backflow prevention devices help protect personnel, by preventing potable water contamination or potable water pollution in critical water supply systems.



Figure 36. Submerged Inlet

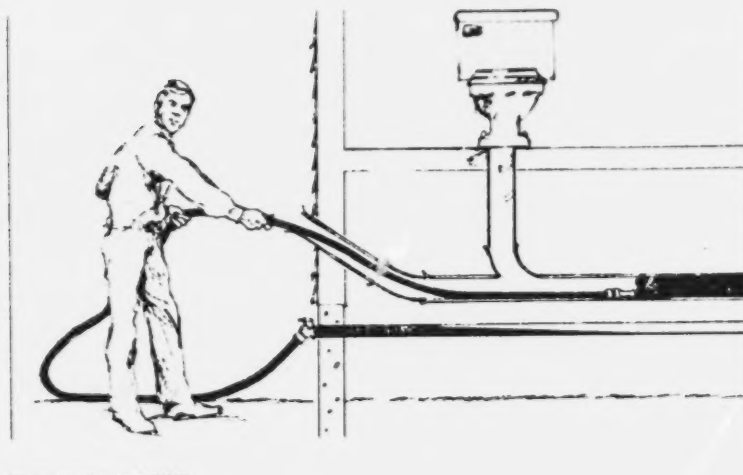


Figure 37. Hose Bibs

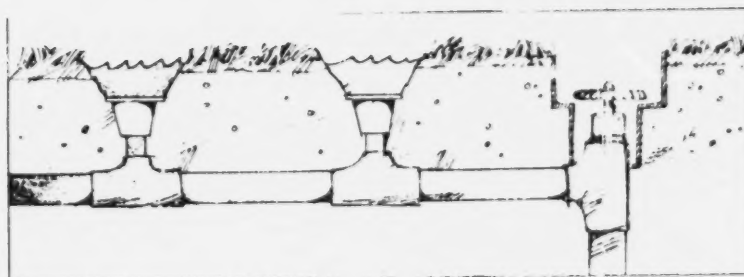


Figure 38. Lawn Sprinkler

AIR CONDITIONING MAINTENANCE

OBJECTIVE

Familiarize you with the maintenance required for air conditioners.

INTRODUCTION

Maintenance of air conditioning systems involves preoperational checks, servicing, operation and correcting problems that develop.

Preoperational Checks

Preoperational checks should be performed on air conditioning equipment after it has been shut down for the heating season. Too often air conditioning equipment has been started before proper checks have been made, resulting in equipment damage.

Check the condenser for cleanliness, condition of fins (air cooled), enough ventilation (air cooled), and proper amount of water flow (water cooled). The evaporator should be checked for the same problems.

Check the fan motors for proper lubrication, secure mounting and correct alignment. The fans should be checked for correct alignment, security on shafts, proper fan clearance and cleanliness.

The condensate drain should be checked very carefully to ensure there is no clogging. When a condensate drain stops up, very serious problems to other equipment, within system, could result.

The power supply should be checked to ensure proper voltage is supplied to unit. Most air conditioning equipment requires its own source of power because this equipment has high amperage draws. Therefore, it is not safe to install other equipment or appliances in the same circuit.

QUESTIONS

1. What could happen to equipment when there is no preoperational check? _____

2. What should the condenser be checked for? _____
3. The fan motors should be checked for _____

4. What could result if a condensate drain was stopped up? _____

5. Why should A/C equipment have its own source of power? _____

CHARGING PROCEDURES. Now that the preoperational checks on the unit are completed, your next job may be to charge the unit with refrigerant. Always pressure check the unit for leaks, and evaluate before attempting to charge the unit. The ambient temperature method of charging will be discussed here. With this method, you will continue to charge the unit until a predetermined condensing pressure is reached. To calculate the operating condensing pressure at which the unit will be considered to be fully charged, two factors must be determined. The ambient temperature must be known, and the condenser cooling medium (air or water) must also be known.

QUESTIONS

1. Define the ambient temperature method of charging an air conditioning unit.

2. What two factors must be known to calculate the operating condensing pressure?

To calculate the operating condensing pressure on a forced air cooled condenser, first determine the ambient temperature at the condenser (example 90°F). Add the condensing factor which is 30°F for forced air cooling or 25° for water cooling (90°F + 30°F). Convert the total temperature to refrigerant pressure. This can be done using a pressure-temperature chart, or the pressure-temperature scale on the discharge gauge of your manifold gage assembly (120° = 259.9 psig R-22).

QUESTION

Determine the operating condensing pressure of an R-22 forced air coded unit with an ambient temperature at the condenser of 85°. _____

Now that you know what the operating condensing pressure should be you can vapor charge the unit through the low side, until that pressure is reached.

YOU HAVE COMPLETED THE DIRECTED STUDY AND HOMEWORK ASSIGNMENT IN PREPARATION FOR DAY 38.

START HERE FOR THE DIRECTED STUDY ASSIGNMENT TO BE COMPLETED PRIOR TO DAY 39.

OPERATION OF WINDOW UNIT

Condenser pressure and temperature should be monitored to ensure unit is accurately charged and functioning properly. Care should be taken because excessively high pressures and temperature could result in equipment damage and/or danger to personnel.

Evaporator pressures and temperatures should be monitored periodically. The biggest problem to consider with evaporators is freeze-up, which is caused by low temperatures and pressures.

QUESTIONS

1. What could damage equipment or injure personnel when monitoring condenser operation?

2. What is the biggest problem to consider with evaporator pressure? _____

Air leaving the evaporator must obviously be at a lower temperature than the room temperature to effect any cooling. This temperature difference (air entering coil vs air leaving coil) is usually between 15 and 20 degrees. This is initially a design problem, in which the objectives are to supply sufficient cool air to take care of the heat load and to keep air velocities down to the point where objectionable drafts and noises will be prevented.

QUESTION

What is usually the temperature difference between air leaving and air entering the evaporator? _____

When an air conditioning system is operating, the amperage draw of the compressor should be taken. With the system under a full load, compressor amperage draw should approximate compressor full load amps. The manufacturer of the unit determines the full load amp draw of the compressor. This is determined when the unit is placed under the desired design conditions. If the compressor is drawing more than full load amps, there may be a problem in the system.

NOTE: Remember, while working on the window units in the lab, the units are not under a full load. The amp reading you get will be 20 to 30 percent less than compressor full load amps. Full load amps (FLA) is the amp draw of the compressor under full load at design temp.

QUESTION

What is full load amps (FLA)? _____

After the air conditioning system has been operating for a while (5-10 minutes), the evaporator should be fully active. A fully active evaporator is reached when the entire evaporator surface is absorbing heat. We can determine this by placing our hand at different locations on the evaporator and feeling the temperature. This temperature should be about the same in every location. When there is high humidity and the entire evaporator is sweating this is another indication of a fully active evaporator.

What is a fully active evaporator? _____

There are two areas of trouble to consider when troubleshooting an air conditioning system. They are the refrigeration system and the electrical system.

The refrigeration system has its problems within the closed portion of the system. Troubles inside the unit may include:

1. Lack of refrigerant
2. Stuck compressor
3. Inefficient compressor
4. Clogged refrigerant circuit

The electrical system includes all the controls and fan motors which are located externally. Some of these items are:

1. Faulty T-stat controls/motor controls
2. Faulty switches (push button or rotary)
3. Faulty capacitors (shorted or open)
4. Bad relays
5. Bad fan motors (bad motor windings and/or bearings)

In almost all of the above electrical troubles, you would have to remove and replace each faulty item.

Safety: Be very cautious when working on systems when power is applied because of the electrical shock hazard.

QUESTIONS

1. What are the two main areas for troubleshooting air conditioning systems? _____

2. Name three problems that can be found within refrigeration systems. _____

3. Name one problem an electrical system could have. _____

COOLING TOWERS, WATER TREATMENT AND EVAPORATIVE CONDENSERS

OBJECTIVE

Familiarize you with the operating principle of cooling towers, purpose of bleed off, make-up water and methods of capacity control.

INTRODUCTION

Cooling towers are used to cool water. The recirculated water is in turn, used as the cooling medium to transfer heat from refrigeration condensers. This then is the primary function of all cooling towers.

Cooling Towers

The purpose of cooling towers application is to conserve water. This is not too difficult to understand if we realize that thousands of gallons of water are circulated through the condensers each day. "Once through" water, because of cost or regulation, is prohibited.

This in turn presents several operating and maintenance problems.

QUESTION

What is the purpose of a cooling tower? _____

Principles of Operation

The basic principle that all cooling towers are based on is evaporation, or vaporization. How is evaporation effect used to cool water? The principle is based on the law of heat flow--hot to cold--and the change of state in a substance--a liquid changing to a vapor is referred to as evaporation. When air molecules and water molecules come in contact there is heat transfer (sensible heat), from the water to the air. Cooling towers are designed to operate under specific conditions, and the wet bulb temperature of the air. That is, the tower can only cool the condenser water to within the approach temperature. For example, a cooling tower has an approach temperature of 10°F and a condenser water temperature set at 70°F. Now on a particular day the wet bulb temperature increases to 75°F. The tower will only be able to cool the water to 85°F. The term "approach" is used to indicate cooling tower capacity.

(wet bulb temperature) + (approach temperature) = (water temperature)

75°F + 10°F = 85°F (85°F return water from cooling tower)

QUESTION

What principles are all water cooling towers operate on? _____

It is important to gain an understanding of this principle of operation, to allow us to function as operators and maintenance crews in the Civil Engineering field.

In another section we will learn some of the factors which affect cooling towers efficiency. (Troubleshooting)

Types of Cooling Towers

Cooling towers can be grouped in two basic types, natural draft and forced draft. These basic types can further be classified on the basis of air flow in relation to water flow.

A cooling tower is an enclosed device, designed for the evaporative cooling of water by direct contact with the air.

NATURAL DRAFT. A natural draft cooling tower is dependent on its design features and atmospheric conditions, wind velocity, wet bulb temperature and other conditions which can not be controlled, to affect the cooling process.

Natural draft towers must be located in a position where the natural flow of air is not obstructed. Air flow should be 3 to 5 miles per hour. The rate of water flow is usually set at a rate of 5 gpm per ton of refrigeration.

A basic cooling tower (figure 13) consists of water spray, a collecting pan, drain connections, and a structure of louvers or solid panels which form an enclosure or spray chamber. A pump is provided for the recirculation of the cooled condenser water. Most cooling towers are equipped with an adjustable bleed-off to help reduce scale and corrosion.

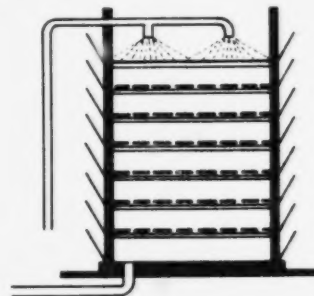


Figure 39. Schematic Diagram of a Natural Draft Cooling Tower

QUESTION

What would be the disadvantages of a natural draft cooling tower? _____

FORCED DRAFT TOWERS. The terms here are related to the design of these towers. Fans are used to "force" the flow of air, which can be controlled, to affect both the quantity and velocity of air, especially when adjustable dampers are used in the air flow stream. Two advantages are gained: 1) smaller systems for a given capacity, 2) closer control of tower cooling capacity.

Regardless of which type of cooling tower is in use, with air conditioning, approximately 1.8 gallons of water will be evaporated per hour for each ton of refrigeration capacity, based on 8.3 pounds per gallon and 900 Btu per pound (average).

QUESTIONS

1. How many gallons would be evaporated in 24 hours for a 5 ton unit? _____

2. List two advantages of forced draft cooling tower. _____

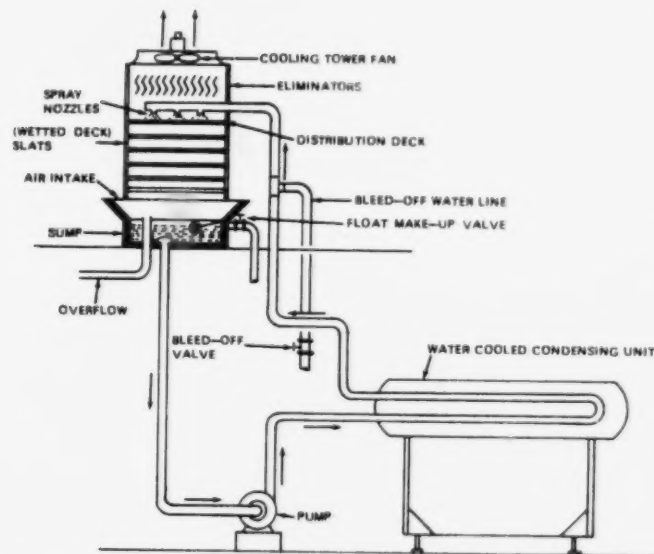


Figure 40. Schematic Diagram of a Forced Draft Cooling Tower

3. List the primary purpose and function of water cooling tower, condenser and pump.

4. Calculate the water requirements for a water cooled system

a. Without a cooling tower, 3 gallons per minute/ton, using a five ton unit, water used one hour. _____

b. Using a cooling tower, water evaporated 1.8 gal/hr/ton. _____

Methods of Cooling Tower Capacity Control

Capacity control of cooling towers is a function that is related to two operating factors. One is the ambient condition of the cooling tower, and the other is the load condition--heat of process or produce--affecting the refrigerant cycle.

A sharp drop in temperature at the cooling tower (DB temp) or increase of WB temperature could affect the cooling capacity of the cooling tower. Requiring a change in air flow or modulating the water flow.

At the load end, evaporator or condenser, heat added from load or ambient would require an appropriate response at one or more cooling tower capacity controls.

Methods

1. Modulating the water flow.
 - Three way valve
 - Butterfly valve
 - By-pass valve
2. Modulating air flow
 - Dampers at the outlet of air flow
 - Multi-speed fans
3. Cycling the fan
 - On-off

QUESTIONS

1. What are the two factors which affect the capacity of cooling towers capacity?

2. List three methods of capacity control and what variable is being sensed. What agent-medium is each affecting?

NOTE: Refer to Figure 41, Cooling Tower Capacity Control Diagram.

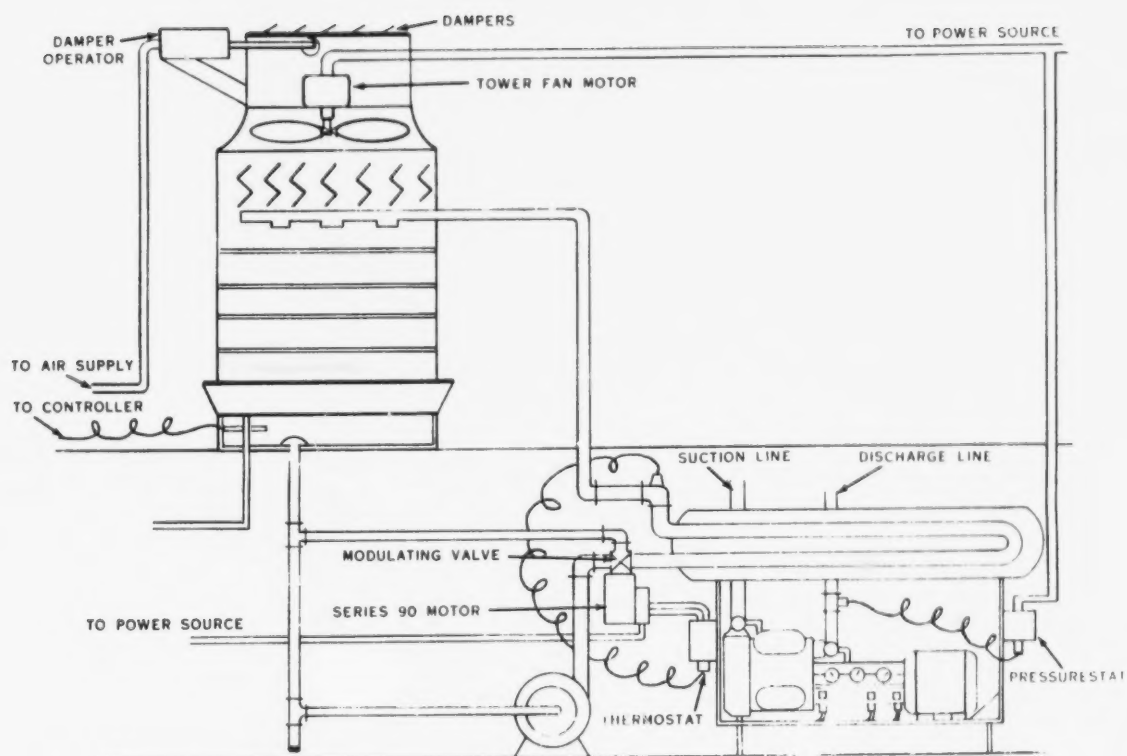


Figure 41. Cooling Tower Capacity Control Diagram

Principles of Operation of Evaporative Condensers

Before you can understand the principles of operation of the evaporative condenser it is important to know the principles of construction, various components and their arrangement. Also the function of each component. See figure 42, page 5-6.

CONSTRUCTION FEATURES. Evaporative condensers are built in much the same manner as forced-draft cooling towers, with the condenser tubes replacing the wetted deck and being used as the wetted deck. The fans draw large volumes of air over the wetted surface. The evaporated water absorbs heat directly from the condenser tubes at the rate of approximately 900 Btu for each pound of water evaporated. The evaporative condenser has a slightly greater heat pickup per pound of water evaporated because the air volume itself will create some condensing in the evaporator tubes.

Similar to cooling towers, the evaporative condenser must have a sump, water make up, pump and usually a refrigerant receiver. Capacity control is similar to forced draft cooling towers.

PRINCIPLES OF OPERATION. The heat laden gases from the compressor are discharged into the condenser tubes, in the evaporative condenser, and the condensed liquid is piped into the receiver. Spray nozzles are used for water distribution over the condenser tubes in larger droplets as it is not necessary to provide smaller particles as the condenser itself provides the heat of evaporation. Air enters at the bottom of the condenser tubes, then up through the tube bundle carrying with it the vaporized water to discharge air ducts, which on large systems are provided with modulating dampers for capacity control. Another method of capacity control used in conjunction with modulated dampers is cycling the fan.

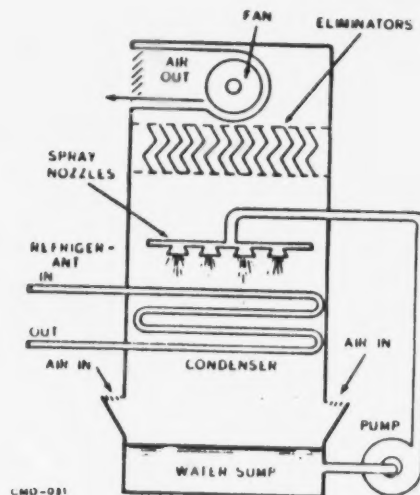


Figure 42. Evaporative Condenser

QUESTION

Why is the evaporative condenser more efficient in heat transfer than other types of condensers? _____

Purpose of Make Up Water

The purpose of make up water is to replace water consumption loss through evaporation, bleed off, wind drift and other small quantities of water loss in condenser water circulation.

Cooling towers are designed to provide a source of water to satisfy the cooling, circulation, and self cleaning requirements through bleed off. There are two basic types of water sumps--dry type and reservoir. The dry sump uses a storage tank located very near or in an inclosed compartment.

Losses through evaporation are calculated at 1.8 gal per hour per ton. Bleed off, used to reduce concentrations of suspended and dissolved solids, can vary between 2-4 gal per hr per ton. Remember, about 970 Btu is required to vaporize one pound of water--one gallon of water weight about 8 pounds.

EXAMPLE: 5 ton unit, how many gal/hr?

	1.8 gal =	14.4 pounds	
X 970	=	13968 Btu/hr	
X 5/ton	=	69840 Btu/hr	
5/ton	=	60000 Btu	=9/gal/hr
9840	=	Heat of compression	

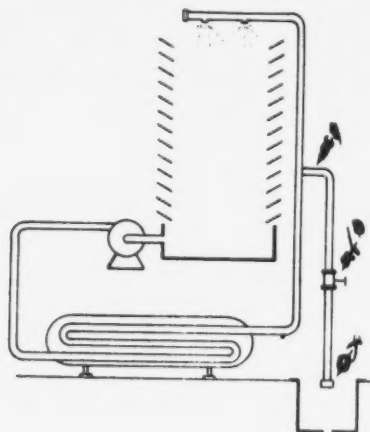


Figure 43. Location of Bleed Line

SUMMARY

Cooling towers are an important part of air-conditioning systems, and if taken care of will give many years of trouble-free service.

The classes of cooling towers are natural draft and forced draft systems.

Cooling tower piping, types of fittings, and types of valves must meet the requirements for the application of the system.

A capacity control system must be used that will allow the system to handle the maximum refrigeration load and also operate at reduced loads. Capacity control is usually provided for by using a modulating water valve that is operated by head pressure.

Cooling tower maintenance and service procedures should be followed to insure an operational system with as little downtime as possible. This can be accomplished by correct water treatment and keeping the system clean.

QUESTIONS

1. What are the two types of cooling towers?
2. At what wind velocity are natural draft towers designed to operate?
3. What is the evaporation rate?
4. What is the purpose of the bleed-off?
5. When using a forced draft tower, how much water must be circulated through the tower?

You have completed the directed study in preparation for Day 39.

REFERENCES

1. AFM 85-18, Maintenance and Operation of Refrigeration, Air-Conditioning, Evaporative Cooling and Mechanical Ventilating Systems
2. Trane Air-Conditioning Manual

Read the following paragraphs and be prepared to discuss the information tomorrow (Day 40) in class. For directed study, prior to Day 40, read the information and answer all questions following.

Calculating Water Bleed-Off

The cooling tower water system should have a bleed-off line installed in a position higher than the water level in the tower sump.

The bleed-off is adjusted to constantly leak or bleed-off a certain amount of water which goes down the drain. The purpose of the bleed-off, as was explained earlier, is to reduce the concentration of minerals in the cooling tower water, which in turn will reduce scale build-up in the condenser. The bleed-off line should be manually adjusted so that enough water is being bled off to control scale build-up, but not so much that water is just being wasted. Bleed off should be adjusted to somewhere between 1-4 gal/hr/ton. For most systems, 2 gal/hr/ton works good. To calculate bleed-off rate, determine the number of second it takes to fill a quart jar (1/4 gal). Bleed rate in gallons per hour = 900 (number of seconds in 1/4 hr) divided by the number of seconds required to fill the quart jar. Gallons per hour per ton is computed by dividing gallons per hour by the tonnage rating of the system.

Start here for directed study to be completed prior to Day 40.

Operation of Cooling Tower and Evaporative Condenser Capacity Control

There are three methods used to control the temperature of the water flowing through the condenser.

MODULATING THE WATER FLOW. The quantity of water flow through the condenser can be increased or decreased (modulated) by using a three-way by-pass valve (figure 41). The valve will decrease the amount of water flowing through the condenser when the condensing pressure/temperature decreases. This is done by by-passing some of the cooling tower water around the condenser and back to the water pump. As the condenser pressure/temperature increases, the three-way modulating valve will by-pass less and less water, sending a larger quantity through the condenser. The position of the motorized modulating valve will be determined by the temperature of the water leaving the condenser. Some evaporative condensers cycle the water pump off when the sump water temperature decreases, and on when the sump water temperature increases.

QUESTIONS

1. What effect will a decrease in temperature of water leaving the condenser have on the three-way modulating valve?

2. As the temperature of the water leaving the condenser increases, how will the modulating valve react?

3. How is evaporative condenser sump water temperature controlled?

MODULATING THE AIR FLOW. You know that cooling towers and evaporative condensers cool by the process of evaporation. You also know that the evaporation is caused by the air flowing through the water that is dripping through or being sprayed into the cooling tower or evaporative condenser. Increasing the air flow will increase the cooling effect, and decreasing the airflow will decrease the cooling effect. Air volume through the cooling tower, or evaporative condenser can be controlled by the position of modulating air dampers located at the air outlet of the tower (figure 41). The dampers would be positioned automatically (pneumatically or electrically) according to the temperature of the water in the tower sump. As the temperature of the sump water increases the modulating dampers will move more toward the open position increasing air flow through the tower and increasing the evaporative cooling effect. If the sump water becomes too cool the dampers will modulate towards the closed position warming the water flowing through the tower. The signal for the dampers to move comes from a thermostat which senses the sump water temperature.

QUESTIONS

1. How does increasing the air flow through a cooling tower or evaporative condenser decrease the water temperature?

2. If the sump water becomes too cool, how does moving the dampers toward the closed position warm the water?

CYCLING THE FAN. This method of capacity control is similar to the modulating dampers explained previously in that it involves changing the amount of air flowing through the tower to change the amount of cooling effect. Where the modulating dampers change the amount of air flow in proportion to the amount of temperature change needed, cycling the fan will either supply full cooling when the fan is on, or no cooling when the fan is off. The tower fan is cycled by a pressurestat that is connected to the compressor discharge line (figure 41). When the discharge pressure increases, the pressurestat will cycle the fan on, cooling the tower water. When the discharge pressure decreases to the pressurestat setting, the fan will cycle off.

QUESTION

What refrigeration system pressure causes the tower fan to cycle?

Read the following paragraphs and be ready to discuss the information tomorrow in class.

Installation of Cooling Towers and Evaporative Condensers

Cooling towers are erected on level structures and must be adequately constructed to withstand their operating weight. Proper space should be provided so that maintenance personnel can readily inspect, service, and repair all components of the cooling tower.

Natural draft towers are usually placed on elevated structures when their location is too close to a building, or they may be installed on the ground when they can be placed far enough away from buildings or other wind obstructions. Allowance must be given for maximum circulation of air through the louvers. Natural draft towers should be located so as to obtain the benefit of prevailing winds during the summer months.

Forced draft towers are mounted on structural steel members. They may be installed indoors or outdoors. If installed indoors, they are usually placed near the outside wall of the building to reduce duct work to the outside. The size of the ducts must never be smaller than the openings of the tower, and square or sharp bends, as well as restrictions in the ducts and louvers should be avoided in the installation, as they reduce the flow of air. Usually the cooling tower water pumps are installed indoors on a level, solid foundation. The pump must always be installed below the level of the water-collecting pan of the cooling tower. The electric motor starter to the tower pump should be interconnected with the compressor motor starter so that the pump motor operates only when the compressor motor is operating.

Usually fittings of cast iron and galvanized steel pipe are used on cooling towers. The pump must have valves and unions so it may be disconnected easily and without draining the system. Gate valves are usually used in system piping because they offer less resistance to water flow. Never install pipe or pipe fittings smaller than the inlet or outlet connection of the equipment. All cooling towers must have a drain line, an overflow line, a bleed-off line, and a water supply line.

Evaporative condensers may be located either on the outside or inside of a building. If located inside, they should be placed next to an outside wall so that a short air inlet duct will supply sufficient outside air for cooling. The size of the duct must be the same as the opening to the unit.

Discharge air outlet ducts must be installed to direct the air away from the air inlet duct. This is done to prevent the warm moist air from returning into the condenser through the inlet duct. The discharge air outlet duct usually terminates in a gooseneck to prevent rain from entering.

Space must be left on all sides of the condenser for servicing, cleaning, and maintenance. Motors, drives, electric switches, and controls must be protected with metal hoods or guards when installed outside.

Evaporative condensers are usually installed inside in climates where freezing weather exists. In freezing climates the only evaporative condensers installed outside are the units that operate only during the summer months for air conditioning.

In freezing climates a means of recirculating the room air through the condenser must be provided for maintaining a proper condensing pressure.

Be sure all evaporative condensers, whether inside or outside installations, are placed on a solid level foundation.

Maintenance of Cooling Towers and Evaporative Condensers

To assure long life and efficient operation, periodic maintenance of cooling towers and evaporative coolers is of prime importance.

- o Keep the water free of dirt, and circulating at full rate. Clean clogged spray nozzles and clean slime and foreign matter from the water distribution pan. Periodically drain and flush the dirt out of the tower. Clean all screens and make sure all lines and pipes are unrestricted.

- o Establish an ongoing water treatment program. Maintain an adequate concentration of phosphates to control the formation of scale and corrosion. Control the growth of algae by adding appropriate algaecides.

- o Make a physical inspection for corrosion so that corrective steps can be taken if evidence of corrosion is found.

- o Determine cleanliness of heat transfer surfaces. Note any abnormal increase in discharge pressure or temperature which may indicate fouled up heat exchanger surfaces or water piping.

Cooling towers and evaporative condensers are an important part of air conditioning systems and if taken care of will last a long time.

Application of Evaporative Condensers

Evaporative condensers are used where lower condensing temperatures are desired than are obtainable with air cooled condensers, and the available water supply may not be adequate for heavy water usage. They were developed originally to alleviate the overburdened water supply and drainage facilities of communities where many small to medium sized air conditioning systems were applied. The sizes offered by various manufacturers will vary, but units are available in a capacity range of 10 tons to 225 tons of gross heat rejection. The primary use of evaporative condensers is to condense refrigerants but they may be used to cool engine jacket waters, oil cooled transformers, or process fluids.

Water Conditioning

This section will help all you future Refrigeration and Cryogenics Specialists to recognize the value of conditioned water, and its effect on the efficiency of air conditioning systems, the problems encountered in water circulating systems, and methods of controlling these problems.

WATER PROBLEMS. Water impurities can be classified as dissolved solids, liquids or gases, and suspended matter. An example of dissolved solid is sodium chloride (salt), or calcium carbonate (scale forming material) in solution. Dissolved materials cannot be removed by filtration. Oxygen and carbon dioxide gasses are also dissolved in water. An example of suspended matter which can be removed by filtration is mud, clay, or silt. The term "turbidity" refers to the amount of obstruction to the passage of light through water resulting from the presence of suspended matter.

SCALE. Scale is a white deposit consisting of compounds of calcium and magnesium. Scale forms from three main activities:

- o Evaporation - As water evaporates, the concentration of dissolved minerals in the remaining water increases.

- o Hardness - Hardness refers to the concentration of calcium and magnesium salts in water, with the degree of hardness being directly proportional to the quantity of calcium and magnesium.

o Reverse Solubility of Calcium and Magnesium - To explain reverse solubility, suppose we take a glass of water at 80°F and dissolve sodium chloride (table salt) in the water. Soon we would saturate the water with salt. No matter how hard we stirred, we could not get any more salt to go into solution. Now, if the same water is heated to 100°F, by stirring we can get more salt to go into solution until the solution is saturated at 100°F. More salt was able to be dissolved into the water after it was heated to 100°F because sodium chloride has direct solubility. A glass of water at 80°F saturated with dissolved calcium and magnesium, when heated to 100°F will cause the magnesium and calcium to separate in solid form from the water because calcium and magnesium have reverse solubility. In other words, as the temperature of the water increases, the solubility of calcium and magnesium decrease. When calcium and magnesium separate from the water onto hot condenser surfaces, it causes scale.

CORROSION. Corrosion of ferrous metals in distribution systems, cooling tower systems and water cooled condensers is a serious problem.

Corrosion of metals may be defined broadly as the chemical or electro-chemical reaction that the metal has with the environment surrounding the metal, often resulting in its deterioration or destruction. As pertaining to water problems, the environment considered will be water. In many conditions, most metals are unstable, and tend to revert to a more stable combination, i.e., they tend to go back to the condition of the metallic ores as found in nature. When metal comes in contact with water, the rate of the metal reverting to the oxide form is increased. As the conditions of the water change, this rate of reversion changes. Some water conditions increase this rate (rapid corrosion) and some conditions retard the rate (minimum corrosion).

o Chemical Corrosion - Corrosion caused by chemical reaction occurs when the water has an acid content. During chemical attack, the metal dissolves into the acid solution. Chemical corrosion can be recognized by uniform deterioration of the metal.

o Electrochemical Corrosion - Electrochemical reaction is similar to the reaction which takes place in a car battery. When two metals of the same type are joined together, they are relatively safe. When two dissimilar metals are in contact, such as brass and steel, a cell results. Metal will be removed from one and will be deposited upon the other. Electrochemical corrosion can be recognized by non-uniform pits and cavities in the metal.

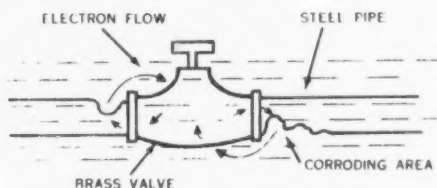


Figure 44. Dissimilar Metals - Cell

ALGAE. Algae are microscopic plants, green or brownish in color which need sunlight to grow. Algae thrive in cooling towers where there is abundant sunlight and high temperatures to carry on their life process.

Slime are bacteria, microscopic animal life, which may or may not require light for growth, depending on the type.

These growths are very common in condenser water systems and less common in closed loop systems. Both types usually enter the cooling water system as airborne particles, but they can also be brought in by birds or by way of makeup water. Many different types of algae and slime can be present in a single system.

Effects of Water Problems

SCALE. Scale is an insulator of heat. Insulating materials similar to asbestos are made of calcium and magnesium compounds. Such materials will prevent the heat of a blow torch from penetrating them. Tests have shown that some scales, the thickness of a dime on condenser surfaces, will reduce the efficiency of the condenser by as much as 50 percent. Scale causes condensing units to operate at higher head pressures. This causes the condensing temperature to become higher which causes even more scale to form.

CORROSION. The products of corrosion cause restrictions by plugging small openings, etc. These restrictions reduce the carrying capacity of the lines, increase frictional resistance and pumping costs. The cost of line replacement, due to damage by corrosion is very high. During repair work, some critical equipment might have to be shut down.

ALGAE. Algae can be extremely troublesome, and is capable of fouling the condenser water system. Algae formations will plug nozzles, and prevent proper distribution of water, leading to high condensing temperatures. Living algae on metal surfaces can accelerate corrosion in the form of pitting, and dead algae can be carried into the system to cause pitting in heat transfer units. Algae prefer water with high temperatures and a pH range from 7.0 to 9.0.

This section will deal with the procedure to chemically treat water for scale, corrosion, and algae.

LABORATORY SAFETY

Before making chemical analysis of water samples, you must be aware of the safety practices that apply to chemical laboratories.

- o Never mix chemicals haphazardly.
- o Do not taste or drink chemicals.
- o Use smallest amount of chemicals necessary to get desired results.
- o Perform experiments at arm's length.
- o Smell gases slowly.
- o Have plenty of ventilation.
- o Always add acid to water, not water to acid.
- o Use face shields, rubber gloves, and aprons when using scale cleaner.
- o If hands or skin burn, flush them with plenty of water.
- o Label all chemicals and tests.
- o Do not close containers that are heating.

The work of a refrigeration specialist in water treatment can be safe if the specialist will use a few simple precautions in the handling and mixing of chemicals, and the handling of glassware and operating equipment. Accidents just do not happen; they are caused by unsafe acts or conditions. The skilled operator knows his chemicals, the proper method of mixing them, the correct manner of operating his equipment, and the importance of keeping his mind on his work. The last is very important because many times after an accident, the victim has remarked, "I wasn't thinking."

Handling Acids and Bases (Alkalies)

Acids and bases (alkalies) can cause severe burns when they come in contact with the skin. When handling chemicals, never put your hands to your eyes or face without first washing them. The skin tissue of your face is more sensitive than that of your hands and is more easily irritated. Rubber gloves must be worn when handling concentrated acid

to protect your hands. To protect your clothes you must wear a rubber apron. Before using these protective devices they should be inspected to assure that they will afford the protection for which they are intended.

When mixing concentrated acids with water, the acid should be slowly poured into the water and the solution should be constantly stirred with a glass stirring rod to prevent a concentration of the acid in a small area of the water. Failure to follow this procedure may result in the acid boiling and splattering the surrounding area, causing severe burns to the operator. NEVER POUR WATER INTO ACID.

COMMON CHEMICALS ASSOCIATED WITH WATER TREATMENT

Most of the chemicals that you will be concerned with in this course are listed in Table of Chemicals, Table 1. The formula, chemical name, and common name or usage that will be important to you are included. NaCl for instance, is the chemical formula for table salt. The chemical name for table salt is sodium chloride. Table salt is sometimes used in refrigeration work as a brine.

<u>FORMULA</u>	<u>CHEMICAL NAME</u>	<u>COMMON NAME OR USAGE</u>
Ca	Calcium	Scale forming element
Ca(HCO ₃) ₂	Calcium Bicarbonate	Temporary hardness
CaCO ₃	Calcium Carbonate	Limestone (scale)
CaCl ₂	Calcium Chloride	Brine
Ca(OH) ₂	Calcium Hydroxide	Lime (water treatment)
CO ₂	Carbon Dioxide	Corrosion helper
Cl	Chlorine	Algae control
HCL	Hydrochloric Acid	Scale cleaner
H ₂ O	Hydrogen Oxide	Water
Mg	Magnesium	Scale forming element
O	Oxygen	Corrosion helper
Na ₂ CO ₃	Sodium Carbonate	Soda Ash (water treatment)
NaCl	Sodium Chloride	Brine and table Salt
NaOH	Sodium Hydroxide	Caustic soda
H ₂ SO ₄	Sulphuric Acid	pH adjustment
Na ₃ PO ₄	Trisodium Phosphate	Surface active agents

Table 1. Table of Chemicals

ACIDS, BASES, AND SALTS

Acids, bases, and salts are chemical compounds linked with waters used in refrigeration systems. The early chemists found that compounds had distinct tastes. Vinegar and lemon juice had a sour taste so the chemists named them "acids" from the Latin word "Acidus," meaning sour.

The second group of compounds such as caustic soda and lime had a bitter taste. This group of compounds would destroy the sourness of acids and would act as a foundation for the manufacturing or making of the third group. Since they acted as a foundation they were called bases.

The third group of compounds was obtained by mixing a base and an acid together. These compounds had a salty taste and were called salts. When these salts are mixed with water, we call them brines. Table salt mixed with water produces a sodium chloride brine. Cold brines are used in ice plants to circulate around fresh water ice cans to produce ice. Brines are very corrosive to metals; therefore, corrosion inhibitors are employed to reduce corrosion. You will perform antifreeze and corrosion inhibitor tests on brines.

Ethylene glycol, the antifreeze similar to that used in your car, is used in chilled water systems to lower the freezing point of water. These solutions are called brines when used for this purpose. However, chemically ethylene glycol is not a brine.

Tests for Acids

The acids you will be most concerned with are hydrochloric and sulphuric. These acids are shown in Table 1.

A very simple test is to place litmus paper in the acid solution. Acids turn blue litmus paper red. Another test for acids is to check the solution with phenolphthalein ("P" indicator). "P" indicator remains colorless when placed in acids.

Concentrated acids such as scale cleaners are very dangerous and must be handled with extreme care. The use of scale cleaners will be covered at a later time. You are cautioned, however, never to pour water into acid. There is an urge in most students to mix chemicals just to see what happens. Remember Rule One of laboratory safety: NEVER MIX CHEMICALS HAPHAZARDLY.

Tests for Bases

Bases are probably not as well known as acids but they are just as important.

Sodium hydroxide is a white, crystalline solid. It is soluble in water, bitter to the taste, feels slippery between the fingers and "burns" the skin. It is known as lye or caustic soda. Next to sulfuric acid, sodium hydroxide is probably the most widely used chemical. It is a very strong base and must be handled with caution.

Bases turn red litmus paper blue. When the pH is above 7.9, bases turn "P" indicator red. Bases are used to neutralize acids.

TESTING FOR pH

Just as a thermometer measures the intensity of heat, pH measures the intensity of an acid or base in solution. pH means potential hydrogen; a hydrogen atom that has lost its electron (H^+); a positive hydrogen atom: a positive hydrogenion. Where many hydrogen atoms lose their electrons, the water solution containing these hydrogen ions becomes very aggressive; so aggressive, in fact, that the water will eat metal right off iron pipes. This aggressive water is acid in nature.

QUESTIONS

1. What does pH mean? _____

2. What does pH measure? _____

pH determines the degree of acid or base in solution. As we explained earlier, with litmus paper and "P" indicator we can determine whether a solution is acid or base, but we cannot determine the degree of intensity. With pH comparators, we can determine not only the nature of the solution but also the intensity of acid or base. Acids contain more hydrogen ions (H^+) than hydroxyl ions (OH^-) and range in pH from 6.9 to zero. Bases contain more OH^- ions than H^+ ions and range in pH from 7.1 to 14.

QUESTIONS

1. What range on the pH scale represents acid? _____
2. What range on the pH scale represents a base? _____

Pure water is made up of H_2O molecules, but also contains H^+ ions and OH^- ions in equal amounts. The pH of pure water is 7.0 which is neutral; neither acid nor base. When there are impurities in water, usually this balance is disturbed and there is more H^+ or OH^- . This causes the water to be acid or base. Going a step further, acids can be identified as those substances which, when dissolved in water, increased the hydrogen ion (H^+) concentration bases as those substances which, when dissolved in water, increase the hydroxyl (OH^-) ion concentration. HCL is an acid. NaOH is a base.

QUESTIONS

1. What is the pH of pure water? _____
2. What does that pH figure indicate? _____

It has been found that the hydrogen and hydroxyl ion concentration of pure water is 0.0000001 gram per liter. This is equal to $1/10^7$ grams per liter and a pH of 7.0. If the hydrogen ion (H^+) is increased, say, 10 times, there would then be 10 times 0.0000001 gram per liter or 0.0000001 = $1/10^6$ grams. The pH value of the water would then be expressed as 6.0. A pH of 5.0 is 10 times more acid than a pH of 6.0.

The relation between H^+ , OH^- , and pH values is shown in figure 45.

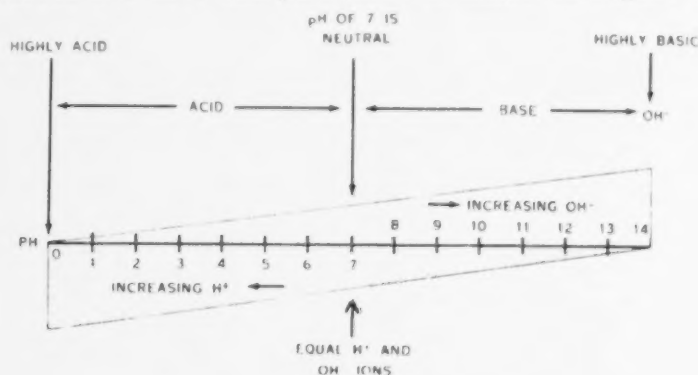


Figure 45. pH Relationship

What is the difference in acid content of water with a pH of 5, and water with a pH of 6? _____

Note that as the pH value decreases, the H^+ increases and the OH^- decreases. At zero pH, the H^+ is at maximum and OH^- at minimum. For basic waters the reverse is true. As the water becomes more basic, the concentration of OH^- increases but the H^+ decreases. At pH 14, OH^- is at maximum and H^+ is at minimum.

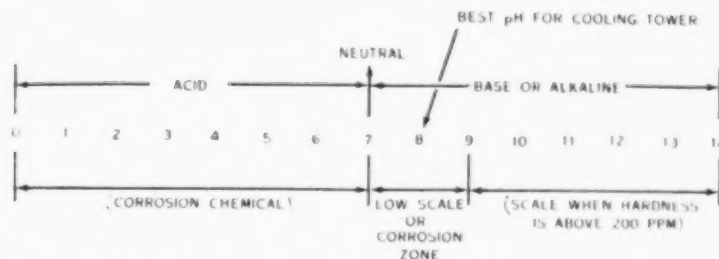


Figure 46. pH Adjustment

What is the best pH for cooling tower water? _____

pH VALUE. The pH value of water is commonly determined by two basic methods. The simplest and most accurate method, is by means of an electronic "pH meter." This device measures pH by determining, with a potentiometer, the voltage developed by two electrodes which are in contact with the water. The voltage of one electrode known as a calomel half-cell is fixed, while the voltage of the other electrode varies with the pH of the sample.

The color comparator method may also be used to measure the pH value of water, but with less accurate results. With this method a suitable indicator (reagent) is added to the water sample, and the resulting color is compared with fixed color standards for that particular indicator. In most water test kits, the color standards are available in sealed glass ampoules, color disks, color strips, etc. A disadvantage of the color comparator method is that colors resulting from tests usually do not exactly match the color comparator, but instead have a shade between two adjacent color standards. It is necessary then to estimate the results.

QUESTIONS

1. List the two basic methods of determining the pH of a sample of water.

- a. _____
- b. _____

2. Which of the two methods is most accurate?

3. Explain why the other method is not as accurate.

CHEMICAL TREATMENT OF WATER. If the water supply is extremely hard, it may be necessary to soften the make-up water with a zeolite-type softener. Zeolite softeners exchange the non-scale forming element, sodium, for the scale forming elements calcium and magnesium. Hardness in make-up water may be softened to near zero with this type of unit. Zeolite softening does not decrease the alkalinity of the make-up water, however, and so a bleed-off is still required. When the softener becomes loaded with calcium and magnesium, it is regenerated by passing sodium chloride (table salt) through the zeolite compound, then flushing the zeolite section with fresh water. Occasionally some zeolite must be added to replace that lost in flushing. This method of treatment is rarely used on condenser water systems because the large quantity of water going through it results in frequent regenerating which gets expensive.

1. Explain how zeolite softeners treat water for scale.

2. How is the zeolite softener regenerated?

3. Explain why this method of water treatment is not often used. _____
- _____
- _____
- _____

POLYPHOSPHATES. Some materials inhibit crystal growth and thereby prevent scale formation. These surface active agents increase the solubility of the scale forming salts and permit an oversaturated condition to exist without precipitation from solution. Some of these materials are polyphosphates, tannins, lignins, and starches. Polyphosphates in concentrations of 2 to 5 parts per million (ppm) are commonly used to prevent or reduce scale formation. At 100°F, scale starts to form in untreated water when the hardness is 200 ppm. With the treated water, however, scale does not form until the hardness reaches 800 ppm.

QUESTION

How does adding polyphosphates to the condenser water system keep scale from forming in the condenser? _____

SULFURIC ACID. Scale formation may also be controlled by reducing the pH value of the water. This may be done by adding acid and corrosion inhibitors to the water. A greater concentration of total dissolved solids is possible when acid is added to the system. Sulfuric acid reacts with bicarbonates and converts them to the much more soluble sulfates. Thus, acid reduces the alkalinity, lowers the pH value and permits a greater concentration of dissolved solids without scale formation. Corrosion inhibitors prevent acid from attacking the metal surfaces. Acids should be fed into recirculating water systems by automatically controlled systems to prevent excessive acid additions.

1. How does adding sulfuric acid to the condenser water system keep scale from forming in the condenser? _____
- _____
- _____
- _____

2. What method should be used to add acid to the condensing water? _____
- _____
- _____
- _____

CHEMICAL TREATMENT OF WATER FOR CORROSION. Polyphosphates are widely used in condenser water systems for corrosion control. They restrain the corrosion reaction, which is the dissolution of the metal, by forming a protective film on the metal. For this type of corrosion treatment to be effective, enough polyphosphate inhibitor to protect the entire area must be added.

QUESTION

How does phosphate treatment prevent corrosion? _____

CHEMICAL TREATMENT FOR ALGAE. Chemical treatment, rather than removal by mechanical cleaning, is a more satisfactory method of combating algae because of their inaccessibility in the system. If, however, algae is allowed to form an appreciable deposit, it should be removed where practical by mechanical means, and flushed from the system before chemical treatment is applied.

Frequently, micro-organisms build up an immunity to a particular algacide. This characteristic makes it necessary to change to other compounds periodically. Experience has shown that the treatment of algacides in shock doses is more effective and economical than continuous treatment. Also, alternating between different types of chemicals adds to the effectiveness of the treatment. One way to control the growth of algae is manual applications of calcium hypochlorite to the cooling tower deck. Calcium hypochlorite is about 70% chlorine. It should be added at the rate of about 202/1000 gallons of cooling system capacity one to three times weekly. Calcium hypochlorite is commonly available in crystalline form. Copper sulfate is another effective algacide. It is effective because as little as 0.5 ppm kills most common forms of algae. Copper sulfate, however is corrosive to steel.

QUESTION

1. Why is chemical algae treatment more effective than mechanical cleaning? _____

2. How does alternating between different types of algacides add to the effectiveness of the treatment? _____

3. List two types of algacides.

a. _____

b. _____

You have completed the directed study to be completed prior to Day 40. Read the following paragraphs and be prepared to discuss the information tomorrow in class.

Cooling Tower Water Conditioning Equipment

DRIP FEEDER. The drip feeder can be either gravity or automatic feed. The automatic feeders are calibrated at the factory to insure accurate feeding. The chemical solution is placed in a container located above the tower sump. The solution drips into the tower water through a small line from the solution container. The rate of flow is controlled by a needle valve in the feeder line. The automatic feed type use a solenoid valve actuated by the recirculating pump in the system so that the valve will open and close as the pump starts and stops. A constant level reservoir provides a steady head pressure to an adjustable needle valve, which is set to drip at a predetermined rate. The adjustment of a drip feeder will be the needle valve which is adjusted to the chemical manufacturers specifications.

POT FEEDER. The pot type feeder is a small cylinder type unit, usually made of clear plastic, which can be mounted on a wall or a stand next to a receiving tank or tower sump. Operating pressure is supplied by the water system from which makeup water is received. All connections are through acid-resistant plastic tubing. This unit has a plastic water operated injector for feeding acid more easily and accurately into an open sump. Makeup water is passed through the injector at a rate not greater than the makeup water requirements. The feeding of acid into the system is controlled by a graduated dial on a valve in the injector. The acid is diluted with water within the plastic body of the injector before it reaches the circulating water. This injector may be used to inject diluted acid through the intake side of a circulating water. This injector may be used to inject diluted acid through the intake side of a circulating pump, if the pressure is low enough, into a closed system.

The pot type feeder may be used to add liquid or briquette chemicals (figure 49). To fill the tank with chemicals, close the inlet and outlet valves. Then open the bleed, fill and drain valves. When all the water has drained from the tank, close the drain valve and fill the tank with the desired chemicals. To place feeder into operation, close the fill and bleed valves. Now open the inlet, outlet and metering valves. Adjust the metering valve to the desired chemical flow while observing the slight indicator. Pressure from the circulating pump forces water up through the pump where a small portion of it goes back through the chemical feeder. The larger amount goes to the air conditioning system.

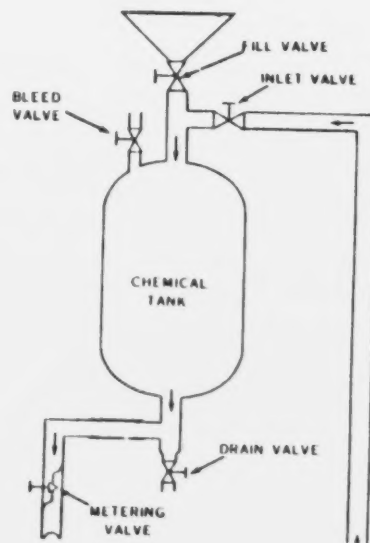


Figure 47. Pot Type Chemical Feeder

The main adjustment on the pot feeder is the metering valve which should be adjusted to the chemical manufacturers specifications.

Maintenance of Evaporative Mechanical Equipment

All evaporative mechanical equipment operates on the same principle. Evaporation of moisture removes sensible heat--either from other water, or from air passing through it. Maintenance of this type of equipment (cooling towers, evaporative condensers, evaporative coolers, etc.), is aimed for a large part toward the problems caused by the water that the system is using. Treating the water systems were discussed in the previous section so this section will be directed toward other maintenance.

- o Remove rust and apply protective paint.
- o Lubricate motors and bearings.
- o Check drive belts for proper tension and wear.
- o Check filter pads (evaporative coolers) for cleanliness and deterioration.
- o Check spray nozzles for obstructions.
- o Remove scale and algae deposits.

Technical Training

Refrigeration and Cyrogenics Specialist

FUNDAMENTALS OF AIR CONDITIONING



3700 TECHNICAL TRAINING WING
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

DESIGNED FOR ATC COURSE USE

DO NOT USE ON THE JOB

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CIVIL ENGINEERING MAINTENANCE MANAGEMENT

Part 1

OBJECTIVE

Using material provided, identify basic facts and terms relating to Civil Engineering Maintenance Management functions with 80% accuracy.

PROCEDURE

Match the Civil Engineering Maintenance Management function in the left column to the definition in the right column. Each function may be used more than once. Not all definitions will necessarily be used.

- | | |
|---|---|
| | 1. _____ AF Form 332 |
| a. Work Request | 2. _____ Work needing detailed planning |
| b. Service Call | 3. _____ Material Control |
| c. Work Order | 4. _____ Request for minor construction work |
| d. Job Order | 5. _____ Request for work that does not require detailed planning |
| e. Management and Utilization of Material Resources | 6. _____ Used to authorize work that needs detailed planning |
| | 7. _____ AF Form 732 |
| | 8. _____ Work done, authorized by AF Form 1879 |
| | 9. _____ AF Form 327 |
| | 10. _____ Request for Real Property Maintenance |

FUNDAMENTALS

Part 1

OBJECTIVE: Given a series of incomplete statements, explain basic facts concerning the types and purpose of air conditioning equipment, and state the principles of air conditioning fundamentals with 80% accuracy.

PROCEDURE: Complete the following incomplete statements by filling in the blanks with a word or words chosen from the list below.

1. Air conditioning is defined as that process used for the control of _____, _____, and _____ of air.
2. A _____ is an example of a self-contained or unit cooler.
3. A _____ is an example of a remote unit.
4. Equipment cooling is maintaining _____ and _____ within a close tolerance.
5. Humidity control equipment will either _____ or _____ the air.
6. Humidity control systems can be either _____ or _____.
7. Air filtration equipment is used to control the _____ of the air.
8. Filters are classified as _____ or _____.
9. Fans are used for _____ and _____.
10. The two main categories of fans are _____ and _____.

ANSWERS

Central System
Permanent
Temperature
Humidify
Ventilation

Window Unit
Radial
Humidity
Circulation
Electric

Purity
Humidity
Dehumidify
Axial
Filtration

Pneumatic
Throwaway
Circulation
Temperature

Part 2

OBJECTIVE: Using material provided, list the procedures for installing air conditioning equipment, and identify the process for assuring the security of mounting of refrigeration, water, electric lines, and sytem components, with 70% accuracy.

Exercise a.

PROCEDURE: State installation procedures by answering the following questions. You may use your study guide or notes.

1. The evaporator should be installed so that it is _____ and _____.

2. How is permanent alignment insured when installing a fan and motor? _____

3. Where should large fans be installed? _____

4. Where should the filter bank be installed? _____

Exercise b.

PROCEDURE: Match the method of security of mounting in the right column below with the correct item from the left column. Some methods may have more than one answer.

- | | | |
|----------------------------|----------|--|
| a. Conduit | 1. _____ | Support at regular intervals to prevent sagging and vibration. |
| b. Soft drawn copper lines | 2. _____ | Will cause copper tubing to crystallize and crack. |
| c. Electrical lines | 3. _____ | Should be supported similar to tubing. |
| d. System components | 4. _____ | Inserted between tubing and clamp to protect tubing. |
| e. Hard drawn copper lines | 5. _____ | Should not be supported by tubing. |
| f. Water lines | 6. _____ | Used to protect tubing run through a wall or floor. |
| g. Vibration | | |
| h. Insulation | | |
| i. Refrigeration lines | | |

Part 3

OBJECTIVE: Using a psychrometer, determine the wet and dry bulb temperatures of the air in the classroom, and using those temperatures, plot dewpoint temperature, relative humidity, specific humidity, and heat content on a psychrometric chart with instructor assistance.

PROCEDURE: Record the wet bulb and dry bulb psychrometer readings taken in a classroom on the chart below.

DRY BULB TEMPERATURE	WET BULB TEMPERATURE	WET BULB DEPRESSION

Using the psychrometer readings previously taken, and a psychrometric chart (FO J3ABR54530 001-IV) plot the relative humidity, dewpoint temperature, specific humidity, and heat content of the air in the classroom, and record those values on the chart below.

DB	WB	RH	DP	Gr/lb	HC

Exercise b.

PROCEDURE

Match the method of security of mounting in the right column below with the correct item from the left column. Some methods may have more than one answer.

- | | | |
|----------------------------|----------|---|
| a. Conduit | 1. _____ | Support at regular intervals to prevent sagging and vibration |
| b. Soft drawn copper lines | 2. _____ | Will cause copper tubing to crystallize and crack |
| c. Electrical lines | 3. _____ | Should be supported similar to tubing |
| d. System components | 4. _____ | Inserted between tubing and clamp to protect tubing |
| e. Hard drawn copper lines | 5. _____ | Should not be supported by tubing. |
| f. Water lines | 6. _____ | Used to protect tubing run through a wall or floor |
| g. Vibration | | |
| h. Insulation | | |
| i. Refrigeration lines | | |

Part 4

OBJECTIVE: Using material provided, state simple facts relating to installation of insulating materials with 80% accuracy.

PROCEDURE: Complete the following sentences with facts chosen from the list below relating to installation of insulating materials.

1. Materials having extremely low heat-conduction capacity are called _____ materials.
2. _____ means that the "R" Factor should be high enough to avoid resorting to great thickness of material to increase thermal resistance.
3. The ability to resist absorption either as free water, or water vapor defines _____.
4. Moisture _____ conductivity of heat.
5. No insulation should be used that is not _____.
6. During installation of insulation, failure to fill and seal air pockets and cracks will cause large heat losses due to _____ and _____.
7. In applying insulating material, care should be taken that _____ does not circulate through the insulation.
8. The type of easy flowing insulation that can be blown into the space between the studs of a building already constructed is called _____ type.
9. _____ type flexible insulation is easy to install.
10. The two main purposes of insulation are to _____ and _____.

ANSWERS

Support
Conduction
Batt
Retard heat
Insulation

Deteriorate
Vermine proof
Reduce noise
Air
Installation

Convection
Bulk
Low-heat conducting properties
Increases
Application
Moisture resistant

Part 5

OBJECTIVE: Given the information, identify types and state the purpose of air filters with no more than two errors.

PROCEDURE: Match the filter type in the left column to its purpose in the right column.

- | | |
|-----------------------|--|
| a. Adhesive filters | 1. _____ used to control odor in the air. |
| b. Throwaway filters | 2. _____ will kill bacteria in the air. |
| c. Electronic | 3. _____ must be changed daily. |
| d. Activated charcoal | 4. _____ coated with adhesive liquid or oil. |
| e. Ultraviolet light | 5. _____ puts a positive static electrical charge on all particles passing through it. |
| | 6. _____ frame is usually made of cardboard with wire reinforcement. |

Part 6

OBJECTIVE

Given the information, state the procedure for cleaning and replacing air filters with 80% accuracy.

PROCEDURE

Answer the following questions concerning the procedure for cleaning and replacing air filters.

1. When are filters considered to be dirty enough to be cleaned or replaced? _____

2. What is one way to determine if a filter needs to be cleaned or replaced? _____

3. How can you assure the filters are not installed backward? _____

4. What checks should be made when replacing filters? _____

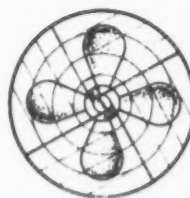
5. What is the first step involved with cleaning electronic filters? _____

FUNDAMENTALS

Part 7

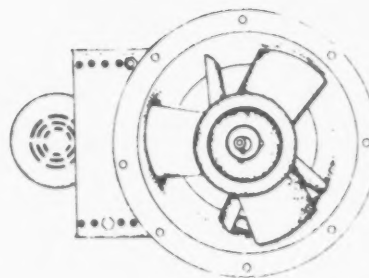
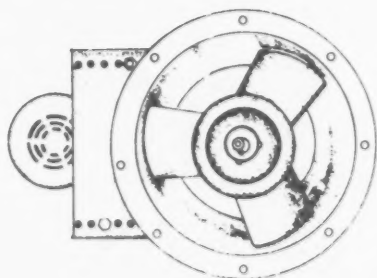
OBJECTIVE: Given the information, identify the types and state the applications of fans with no more than two errors.

PROCEDURE: Identify the following types of fans.



a. _____

b. _____



c. _____

d. _____

PROCEDURE: Match the type of fan in the right column to its application(s) in the left column.

- | | |
|------------------|----------------------|
| a. Circulating | 1. _____ propeller |
| b. Booster | 2. _____ tube axial |
| c. Exhaust | 3. _____ vane axial |
| d. Room | 4. _____ centrifugal |
| e. High Velocity | |

Part 8

OBJECTIVE: Given the information, determine the procedure for installing and servicing fans, and list the methods for aligning drive belts and pulleys, with 80% accuracy.

PROCEDURE: Answer the following questions to determine the procedure for installing and servicing fans.

1. Why must the fan and motor pulleys be installed in close alignment? _____

2. Which type of fan should be installed in air conditioning systems where there is ductwork or other sources of static resistance such as filters? _____

3. How close together should a belt driven fan and motor be installed? _____

List the methods for aligning drive belts and pulleys.

4. _____
5. _____

Part 9

OBJECTIVE: Given the information, compare the relationship between the types of air-flow instruments, state their purpose, and explain their principles of operation with 70% accuracy.

PROCEDURE: Complete the following statements by filling in blanks, answering questions, choosing True or False statements.

1. Air-flow measuring instruments measure the _____ of the air.
2. Air-flow measurements are usually taken at the following locations _____, _____, or _____.
3. Which air-flow measuring instrument has a propeller which moves at the rate of the air speed? _____
4. Which air-flow measuring instrument uses a pitot tube? _____
5. Briefly, compare the relationship between the three types of air-flow measuring instruments.

Circle the correct answer

6. T F The Anemometer reads directly in F.P.M.
7. T F The pitot tube, when inserted into an air duct, senses static pressure and velocity pressure.
8. T F The velometer reads directly in F.P.M.
9. T F The dials on the Anemometer are controlled by levers.
10. T F The manometer measures the velocity pressure of the air in inches of water.

Part 10

OBJECTIVE: Given the information, explain the procedure for using instruments to determine the amount of air flow in an air conditioning system with not more than two errors.

PROCEDURE: Explain the procedure for using air flow measuring instruments by filling in the blanks, and answering the questions below.

1. When using the Anemometer, readings are usually taken at _____.
2. Briefly explain the procedure for using the Anemometer to measure air flow.

3. Explain how to read the dials on the Anemometer after the air flow measurement is taken _____.

4. How is the Anemometer Reading converted to F.P.M.? _____

5. Explain how to convert F.P.M. to C.F.M. _____

6. Explain the procedure for using a velometer to determine the amount of C.F.M. of air flow. _____

7. The pressure indicated on the manometer is known as _____
8. How is the manometer indication converted to C.F.M.? _____
9. Using the information provided, fill in the missing values in the tables below.

	VELOMETER AVERAGE READING	DUCT SIZE	DUCT AREA	FPM	CFM
a	500	12" X 12"			
b	750	12" X 18"			

	ANEMOMETER READING	DUCT SIZE	DUCT AREA	ELAPSED TIME	FPM	CFM
a	1350	42" X 12"				
b	880	24" X 12"				

	VELOCITY PRESSURE	DUCT SIZE	DUCT AREA	FPM	CFM
a	.25	12" X 24"			
b	.36	24" X 36"			

Part 11

OBJECTIVE: Given the information, state basic facts concerning balancing the air distribution in an air conditioning system, with 80% accuracy.

PROCEDURE: Answer the following questions by filling in the blanks, picking True or False, and using the procedure for determining air flow.

1. Explain the purpose for balancing an air distribution system. _____
- _____
- _____
- _____

2. What does the amount of volume of air to be delivered to a room depend on? _____

3. When determining the volume of air to be delivered to a room, the temperature difference between supply and room air must be known. True False (Circle One)

4. Explain the process involved in balancing an air distribution system.

5. Use the following building plan, and specific conditions to determine the volume of air needed to condition the rooms.

FORMULA: $CFM = \frac{ROOM\ HEAT\ LOAD\ (Btu)}{1.08 \times TD}$

NOTE: This formula will determine the CFM needed to handle the HOURLY HEAT LOAD of each room.

DETERMINE THE CFM REQUIREMENT FOR EACH ROOM.

ROOM A. _____

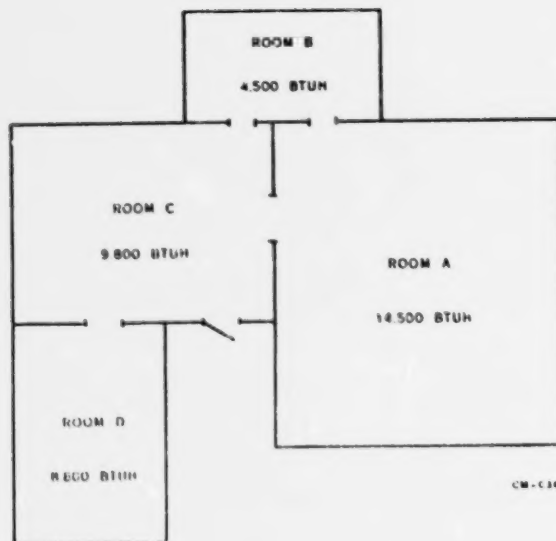
ROOM B. _____

ROOM C. _____

ROOM DESIGN TEMPERATURE -- 75° F (DB)

DESIGN SUPPLY AIR TEMPERATURE -- 52° F (DB)

DUCT SIZES -- ALL 8 inches in diameter.



. Building Diagram

Part 12

OBJECTIVE: Given the information, explain the procedures for maintaining fresh air supply systems, state the methods for checking for excessive leakage in air ducts, and inspecting ducts with 70% accuracy.

PROCEDURE: Explain procedures by filling in the blanks with the correct information.

Explain the needs for supplying fresh (outside) air to an air conditioning system.

1. _____
2. _____
3. _____
4. What is the biggest problem with fresh air systems?

List the conditions for which you would periodically inspect air ducts.

5. _____
6. _____
7. _____

8. How often should air ducts be cleaned?

.....
State what you can do to renew defective air ducts.

9.

10.

WATER PUMPS

Part 1

OBJECTIVE: Given the information, state basic facts or terms relating to the operating principles of centrifugal water pumps with no more than three errors.

PROCEDURE: Complete the following incomplete statements by filling in the blanks with a word or words chosen from the list below.

1. Centrifugal water pumps may be either _____ or _____ suction.
2. In the _____ pump, the water enters from one side of the impeller only.
3. Centrifugal pumps may also be classified as single or _____ stage.
4. Most centrifugal pumps used in refrigeration work are of the _____ type.
5. The centrifugal pump utilizes the _____ of a rapidly revolving impeller.
6. The liquid is pulled in at the _____ of the impeller and is discharged at the outer rim of the _____.
7. By the time the liquid reaches the _____ of the impeller, it has acquired a considerable _____.
8. The liquid is then slowed down by being led through a _____ (a gradually widening channel in the pump casing).

ANSWERS

Throwing force	Single	Center	Double
Multiple	Operation	Alignment	Single-suction
Water	Volute	Velocity	
Outer rim	single-suction, single stage impeller		

Part 2

OBJECTIVE: Given the information, explain the procedures used to install water pumps, align flexible couplings, replace pump packing, adjust pump packing, check the operation of water pumps, and repair water pumps with 60% accuracy.

PROCEDURE: Refer to the study guide/workbook to answer the following questions.

1. Why must a water pump be installed on a concrete foundation? _____

2. How does the installer know where to position the pump hold down bolts in the wet foundation? _____

3. What is the purpose of the wedges that are placed near the center of the motor and pump? _____

4. Indicate the tool used, and the procedure for checking the angular alignment of the motor and pump shafts _____

5. How can the motor and pump halves be brought into alignment? _____

6. What condition will indicate that the unit is in angular alignment? _____

7. What tool is used to remove old packing from the pump stuffing box? _____

8. Explain the proper way to install the new packing ring over the pump shaft. _____

9. How are the new packing ring joints positioned? _____

10. When the stuffing box is fully packed, how is the packing glazed? _____

11. After the new packing has been properly adjusted, what should be the rate of water leakage? _____

12. List the checks to be made for proper water pump operation.
- a. _____
 - b. _____
 - c. _____
 - d. _____
 - e. _____
13. When disassembling a water pump assembly, list the steps to be taken before the pump can be removed from the base plate for bench work. _____

14. When reassembling a water pump, what should be done to the ball bearings just prior to assembly? _____

15. What is the proper procedure to install the bearings on the pump shaft? _____

Part 3

OBJECTIVE: Given the information, state basic facts or terms concerning cross-connection/backflow prevention to protect potable water supplies, with no more than two errors.

PROCEDURE: State basic facts or terms concerning cross-connection/backflow prevention by answering the following questions. You may use study guide or notes.

1. Define backflow _____

2. Define cross connection _____

3. List 4 types of backflow prevention devices.
 - a. _____
 - b. _____
 - c. _____
 - d. _____
4. Which type(s) may be used for any degree of hazard? _____

5. What should be done prior to installing a backflow prevention device? _____

AIR CONDITIONING MAINTENANCE

Part 1

OBJECTIVE: Working as a member of a team, and using a window air conditioner, perform preoperational checks of the unit, with no more than three instructor assists.

PROCEDURE: 1. Remove jewelry.
2. Use the air conditioning unit indicated by the instructor.
3. Indicate under each component(s) below the type of preoperational check you made, and the condition you found.
4. Have your work checked by the instructor when you have finished.

a. Condenser and evaporator

1. Check _____

Condition _____

2. Check _____

Condition _____

b. Fan motor and fans

1. Check _____

Condition _____

2. Check _____

Condition _____

c. Power supply

1. Check _____

Condition _____

Part 2

OBJECTIVE: Working as a member of a team, and using a window air conditioner, perform equipment maintenance by charging the unit using the ambient dry bulb temperature method. The correct condensing pressure must be reached ± 5 PSI.

PROCEDURE: 1. Remove jewelry.
2. Use the air conditioning unit indicated by the instructor.
3. Have the instructor check your unit after it has been charged with refrigerant.
4. Wear safety goggles when installing gauges.

a. Determine operating condensing pressure.

1. List the steps to determine operating condensing pressure.

b. Charge the unit with refrigerant (wear safety goggles when working with refrigerant).

1. What type refrigerant are you using? _____

2. What part of the system are you charging into? _____

- c. Continue to charge until your estimated condensing pressure is reached.
 1. What is your evaporator temperature?

 2. Is your evaporator temperature within a 40-50° range? _____
- d. Have the instructor check your unit.

Part 3

OBJECTIVE: Working as a member of a team, and using a window air conditioner, operate the unit and determine operating conditions with no more than three instructor assists.

- PROCEDURE:
1. Remove jewelry.
 2. Use the air conditioning unit indicated by the instructor.
 3. Indicate by each operating condition, the condition you found.
 4. Have your work checked by the instructor when you have finished.
 5. Remove power from the unit, remove gauges from the unit (wear goggles), cap access valves, return all equipment to its proper place.

a. Condenser

Pressure _____

Temperature _____

b. Evaporator

Pressure _____

Temperature _____

Return air temperature _____

Supply air temperature _____

Temperature difference _____

% active coil
50% _____

75% _____

100% _____

c. Compressor amperage draw

d. Have instructor check your work.

Part 4

OBJECTIVE: Using the trainer provided, and working as a member of a team, isolate instructor induced system malfunctions to the smallest replaceable or repairable part.

- PROCEDURE:
1. Use the trainer assigned by the instructor.
 2. Analyze the circuit diagram, system controls, and indicating meters and gauges.
 3. Notify the instructor when you are ready to troubleshoot the system.
 4. After the instructor has entered the malfunction, troubleshoot the system using the meters and gauges provided until you have isolated the smallest replaceable or repairable part.
 5. Have the instructor check your work.

COOLING TOWERS, WATER TREATMENT,
AND EVAPORATIVE CONDENSERS

Part 1

OBJECTIVE: Given the information, identify terms and facts relating to the principle of operation, purpose of bleed off, and make-up water, and methods of capacity control of cooling towers and evaporative condensers with no more than four errors. You may reference your notes and study guide.

PROCEDURE: In the following spaces state the principle of operation for cooling towers.

1. _____

List two basic types of cooling towers.

2. Types:

Fill in the blanks.

3. Capacity control of cooling towers is accomplished by:

_____ the water flow, _____
 _____ the air flow, and _____ the fan.

4. Identify terms and facts relating to the operation of evaporative condensers by matching the items in Column 1 with their operation in Column 2. Not all items in Column 2 are correct. You may use notes or study guide for reference.

COLUMN 1

COLUMN 2

a. Fan

1. Directs water to the spray nozzles.

b. Condenser tubes

2. Draws air from the conditioned space.

c. Evaporated moisture

3. Replaces and used as wetted deck.

d. Spray nozzles

4. Draws large volumes of air over the wetted deck.

e. Air

5. Absorbs heat directly from the condenser tubes.

6. Enters at the bottom of the condenser tubes.

7. Distributes water over the condenser tubes.

5. List three methods of capacity control for evaporative condensers.

6. Fill in blanks to complete the following statement.

The purpose of make-up water is to replenish the loss from _____
_____ and _____.

7. Select the statement which most correctly defines the purpose of "bleed-off." Place a check mark () in box.

- ☐ a. Prevents unacceptable concentration of algae-corrosion.
- ☐ b. Prevents unacceptable concentration of suspended and dissolved solids.

Part 2

OBJECTIVE: Given the information, state the procedures to calculate water bleed-off, with no more than one error.

PROCEDURE: (1) Given a list of variables in Column 1 below, select those needed to calculate bleed rate. Indicate by check mark ().

- ☐ a. 550 MM beaker
- ☐ b. Watch reading in seconds.
- ☐ c. Funnel
- ☐ d. Quart bottle
- ☐ e. Strainer
- ☐ f. Key or wrench to open valve.

- (2) Fill in the blanks in the following statement and select correct gallon per hour.

It took 60 seconds to fill _____ which is
divided into _____ to determine _____
hour. Select answer:

- ☐ a. 1.5
- ☐ b. 15.
- ☐ c. 15.
- ☐ b. None of the above.

- (3) How many gal/hr/ton would this be for a five-ton system?
Select correct answer with a check mark ().

- ☐ a. 1.5
☐ b. 2.5
☐ c. 3.0
☐ d. 3.5

Part 3

OBJECTIVE: Given the information, state simple facts concerning the operation of cooling tower and evaporative condenser capacity controls with 80% accuracy.

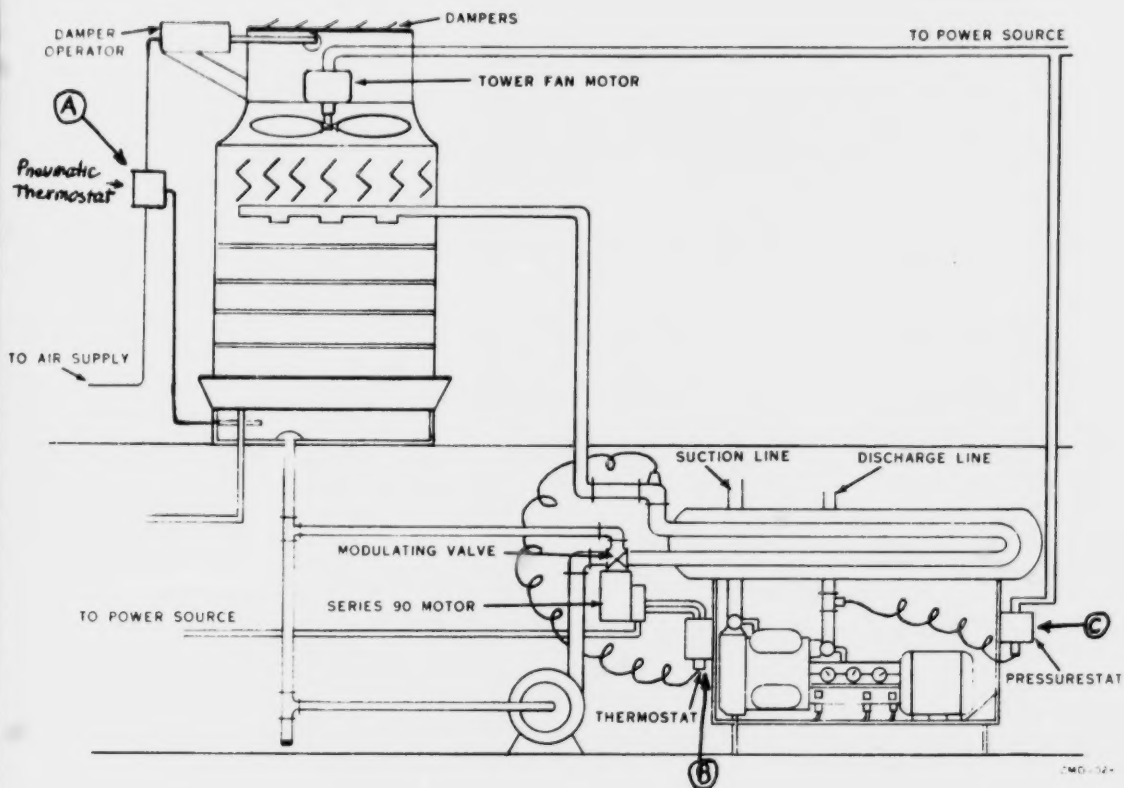
PROCEDURE: Refer to cooling tower capacity.

- (1) Diagram. Fig. 1 Page: 5-4, Items A, B and C are cooling tower capacity controls - Match descriptive phrases in Column 1 with controls in Column 2. These items may be used more than once if applicable.

1.	2.		
	A	B	C
a. Two position	_____	_____	_____
b. Proportional	_____	_____	_____
c. Senses Tower Sump Temp.	_____	_____	_____
d. Senses Pressure	_____	_____	_____
e. Series 90 Final Device	_____	_____	_____
f. Senses condenser Water Temp. Leaving	_____	_____	_____
g. Low voltage	_____	_____	_____
h. Line Voltage	_____	_____	_____
i. Pneumatic			
j. Compressor Discharge Pressure			

- (2) Fill in the blanks with correct terms in the following paragraph.

The evaporative condenser uses _____ and _____ as cooling agents. Capacity control is affected by cycling the tower fan when the _____ increases or decreases. A thermostat cycles off the _____ when the water sump temperature drops below a predetermined setting.



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Figure 1. Cooling Tower Capacity Control Diagram

Part 4

OBJECTIVE: Given the information, describe the procedures to install and maintain cooling towers and evaporative condensers with 80% accuracy.

PROCEDURE: Describe the procedures to install and maintain cooling towers and evaporative condensers by answering the following questions. You may reference notes or your study guide.

1. When are natural draft cooling towers usually placed on elevated structures?

2. When may natural draft cooling towers be installed on the ground? _____

3. When forced draft cooling towers are installed indoors, why are they usually placed near the outside wall of the building? _____

4. What size air ducts are installed on indoor cooling towers? _____

5. What type fittings are usually used when installing a cooling tower? _____

6. What precaution should be taken when installing the discharge air outlet on an evaporative condenser? _____

7. In what instance would an evaporative condenser be installed outdoors in a freezing climate? _____

8. How is a proper evaporative condensing pressure maintained in freezing climates? _____

9. Briefly describe four procedures to maintain cooling towers and evaporative condensers.
- a. _____

- b. _____

- c. _____

- d. _____

Part 5

OBJECTIVE: Given the information, state basic facts or terms relating to the application of evaporative condensers with 80% accuracy.

PROCEDURE: State basic facts or terms relating to the application of evaporative condensers by filling in the blanks below with facts or terms selected from a list at the end of this project.

Evaporative condensers are used where (1) _____ condensing temperatures are desired than are obtainable with (2) _____ condensers, and the available (3) _____ may not be adequate for heavy water usage. Units are available in a capacity range of (4) _____ of gross heat rejection. The primary use of evaporative condensers is to (5) _____.

Higher
Water Supply
Cool Condenser Water
10 tons to 225 tons

Air Cooled
2 1/2 tons to 10 tons
Voltage
Condenser Refrigerant

Part 6

OBJECTIVE: Given the information, state the method to recognize scale, corrosion, and algae with no more than two errors.

PROCEDURE: Give a brief description of scale, corrosion, and algae in the spaces provided for each. You may reference your notes or study guide.

(a) Scale:

(b) Corrosion:

(c) Algae:

Part 7

OBJECTIVE: Given the information, identify basic facts about the effects of scale, corrosion, and algae on an air conditioning system with 80% accuracy.

PROCEDURE: Match the water problem in the left column with its effects on an air conditioning system in the right column. Some items may be used more than once, some items will not be used at all.

- | | |
|---------------|---|
| | _____ (a) Restrictions |
| (1) Scale | _____ (b) Decreased Costs |
| | _____ (c) Line Replacement |
| (2) Corrosion | _____ (d) Equipment Shutdown |
| | _____ (e) Insulator of Heat |
| (3) Algae | _____ (f) High Discharge Pressure |
| | _____ (g) Increased Condenser Efficiency |
| | _____ (h) Lower Operating Discharge Temperature |

Part 8

OBJECTIVE: Given the information, state the procedure for chemically treating water for scale, corrosion, and algae with no more than two errors.

PROCEDURE: State the procedure for chemically treating water by placing a check mark next to the proper method.

- | | |
|-----------|---|
| Scale | ☐ Sodium Zeolite |
| | ☐ Copper Sulfate |
| | ☐ Carbon Oxide |
| | ☐ Polyphosphates |
| | ☐ Calcium Hypochlorite |
| | ☐ Sulfuric Acid |
| Corrosion | ☐ Sodium Zeolite |
| | ☐ Copper Sulfate |
| | ☐ Carbon Oxide |
| | ☐ Polyphosphates |
| | ☐ Calcium Hypochlorite |
| | ☐ Sulfuric Acid |

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- ☐ Sodium Zeolite
- ☐ Copper Sulfate
- ☐ Carbon Oxide
- ☐ Polyphosphates
- ☐ Calcium Hypochlorite
- ☐ Sulfuric Acid

Part 9

OBJECTIVE: Given the information, state simple facts concerning the operation and adjustment of cooling tower water conditioning equipment with 80% accuracy.

PROCEDURE: State simple facts concerning the operation and adjustment of cooling tower water conditioning equipment by answering the following questions. You may reference notes or your study guide.

1. List the two types of drip feeders.

- a. _____
- b. _____

2. Where is the drip feeder located while in use?

3. How is the rate of flow controlled in the drip feeder? _____

4. What is the purpose of the solenoid valve on the automatic drip feeder? _____

5. When will the solenoid valve open and close? _____

6. What adjustment is on the drip feeder? _____

7. What type chemicals may be added to water through a pot feeder? _____

8. Where does water enter the pot feeder? _____

9. What determines the amount of chemicals that enters the water system through the pot feeder? _____

10. What is the adjustment on the pot feeder? _____

Part 10

OBJECTIVE: List simple facts relating to the maintenance of evaporative mechanical equipment with 70% accuracy.

PROCEDURE: Answer the following questions. You may reference your notes or study guide.

1. Explain the principle that evaporative mechanical equipment operates on. _____

Technical Training

Refrigeration and Cryogenics Specialist

AIR CONDITIONING CONTROLS

August 1983



3700 TECHNICAL TRAINING WING
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

DESIGNED FOR ATC COURSE USE

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TABLE OF CONTENTS

Study Guide/Workbooks J3ABR54530 001-V-1 thru V-4

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DIRECTED STUDY ASSIGNMENTS

To Be Completed Prior to Day

41	Pages	<u>1</u>	thru	<u>12</u>
42	Pages	<u>13</u>	thru	<u>24</u>
43	Pages	<u>25</u>	thru	<u>30</u>
44	Pages	<u>31</u>	thru	<u>48</u>
45	Pages	<u>49</u>	thru	<u>53</u>

Supersedes SGs J3ABR54530 001-IV-2, IV-3 and V-4, January 1983

AIR COMPRESSING EQUIPMENT

OBJECTIVE

To acquaint you with the types, purpose and operating principle of air compressing equipment used to support air conditioning equipment.

INTRODUCTION

The following assignments will be completed as indicated for days 41 thru 45. You will be given a quiz at the beginning of each day which will measure information from the designated section of this Study Guide/Workbook.

Homework in preparation of Day 41:

Read the following paragraphs on the air compressor. Answer questions on material covered.

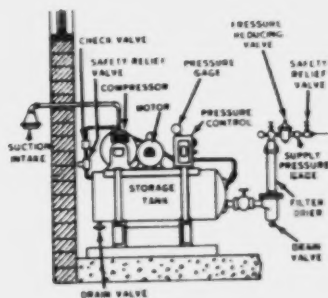
INFORMATION

The air compressor supplies air pressure for the total pneumatic control loop. Most air compressors used with pneumatic control loops are of the reciprocating type. In some applications a screw type compressor is used.

The construction differs by application and size. Most compressors are air cooled, larger sized compressors as used in cryogenics are water cooled. Air compressors may have one cylinder or many cylinders, depending on where they are used.

OPERATION

The air compressor has a suction intake filter to clean the air that goes into the compressor. The compressor pushes the air in the storage tank until the high pressure motor control stops the electric motor that is turning the compressor. When the pressure goes down, the control turns the motor on again. The air leaves the compressor and goes through a filter and on to the pressure-reducing valve which reduces the high pressure to 15-20 psig as required. (See figure 1).



Air Compressing System

Figure 1

Operator Service and Maintenance

Suction Intake Filter

- a. Cleaned each 30 days replaced twice a year.

NOTE: A greater frequency of cleaning and replacement may be required depending on location and amount of dust and dirt in the air.

Belt Adjustment

- a. Tension and condition checked each 30 days.
- b. Should deflect approximately 1/4" with normal hand pressure.

Oil Level

- a. Check each 30 days changed each 500 operating hours.
- b. Use a paraffin base oil specially designed for compressors.

Oil Filters

- a. Replaced each 90 days.

Draining of Air Tank and Air Line Filter

- a. Daily.

Reducing Valve Output Pressure

- a. Check Pressure Daily.

Safety Devices and Controls

- a. Checked each month.

The frequency of service and maintenance given, is only to be used as a general guide. Follow recommendations stated by the manufacturer of the compressor assembly.

Part of your work in the refrigeration field will be installation and replacement of defective parts on the air compressor.

Steps for Installation

1. Select a compressor of proper size and construction.
2. Select a location free from excessive dust and moisture with ample light and space for servicing.
3. Mount the compressor level with a substantial base, 12-18 inches from wall.
4. Check compressor for security of mounting, and valves for proper operation.

Steps for Replacement of Defective Parts

1. Remove all jewelry.
2. Disconnect power to unit.
3. Replace defective part(s) with replacement part(s).

Also checking equipment operation, and operator service and maintenance will be part of your job.

Checking Equipment Operation

1. Observe compressor for correct direction of rotation.
2. Check for abnormal noises.
3. Check for leaks and overheating.

Operator Service and Maintenance

1. Tanks drained daily.
2. Air filter cleaned each 30 days.
3. Oil changed each 500 operating hours.

QUESTIONS

1. Name two cooling agents used to cool air compressors.

2. What is the purpose of an air compressor system when used in a pneumatic control loop? _____

3. Briefly explain the principle of operation of an air compressor assembly. _____

4. List the four steps in order of installation of an air compressor.
 - a.
 - b.
 - c.
 - d.
5. What is the first step to follow when replacing defective parts on the air compressor assembly?

6. List the three steps in order for checking equipment operation?

7. Name three operator service and maintenance procedures that should take place on the air compressor assembly.

PNEUMATIC CONTROLS

OBJECTIVE

To learn the purpose, principle of operation and adjustment of pneumatic controls.

INTRODUCTION

One of the greatest problems in air conditioning is the control of the cooling and heating effects. Automatic controls are used to solve this problem by sensing and controlling the amount of heating or cooling.

An automatic control system must have some type of energy for operation. Pneumatic controls use compressed air for operation, and electric and electronic controls use electricity for operation. This study guide pertains only to pneumatic controls.

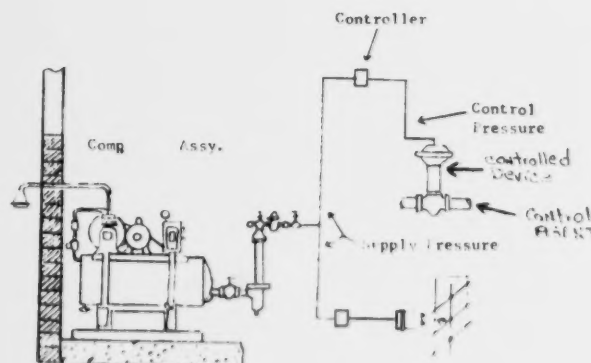
It has been found that the basic control concepts, taken for granted by personnel working in the control industry, are not generally known or understood by the layman.

This Study Guide/Workbook will prepare you for the indicated days of instruction. You must complete the assignments and be prepared for evaluation at the beginning of each day.

DIRECTED STUDY

Assignment in preparation for Day 41.

Read the following pneumatic control terms and refer to Figure 2 to answer the questions.



Pneumatic Control System

Figure 2

Control System: A group of components that regulate temperature, pressure, humidity.

Controller: Thermostats, pressurestat, humidistat. Instrument for controlling the variable within a conditioned space.

Supply Pressure: Compressed air fed to the controller.

Control Pressure: The output pressure for a controller, it varies with temperature, pressure, or humidity.

1. _____ Pressure is the energy source supplied to the controller.
 2. _____ is the output pressure from a controller.
 3. What causes a controller to change control pressure?
-
-

Read the following pneumatic control terms and answer the questions.

Control Response

Two Position Response: Zero or total control pressure.

Proportional Response: Zero or total control pressure and anywhere in between.

Control Action

Direct Acting: A controller that increases control pressure as temperature, pressure, or humidity increases.

Reverse Acting: A controller that increases control pressure as temperature, pressure, or humidity decreases.

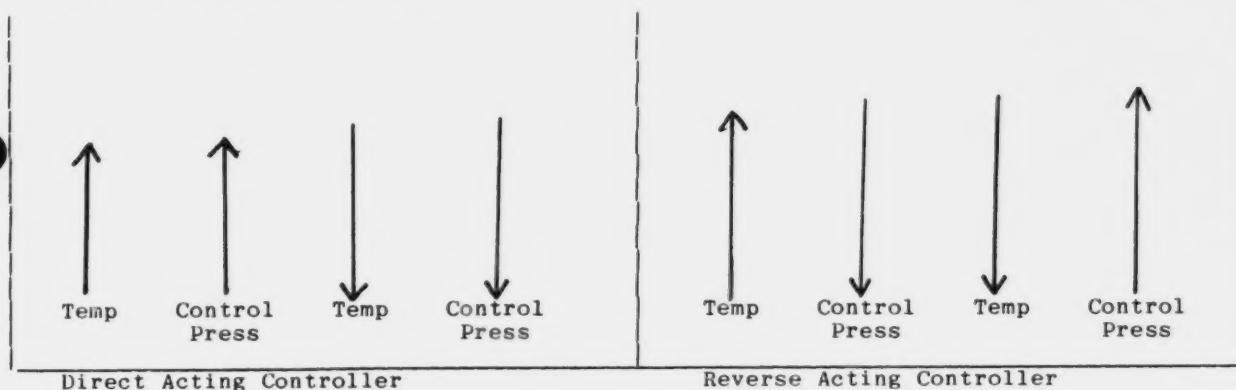


Figure 3

Control Device: A component which, regulates the flow for water, air, or steam such as a valve or damper assembly.

Normally Open: A controlled device that is open when control pressure is removed.

Normally Closed: A controlled device that is closed when control pressure is removed.

Control Agent: Water, air, or steam regulated by a controlled device which effects the temperature, pressure, or humidity.

1. What is the response of a controller, which produces only on and off response?
2. What is the response of a controller that produces a small change in control pressure for a small change in variable (temp, pressure, or humidity).

3. What component in the pneumatic control loop directly controls the control agent?
4. What is the action of a controller that increases control pressure as the variable (temp, pressure, or humidity) increases?

Pneumatic Component Identification

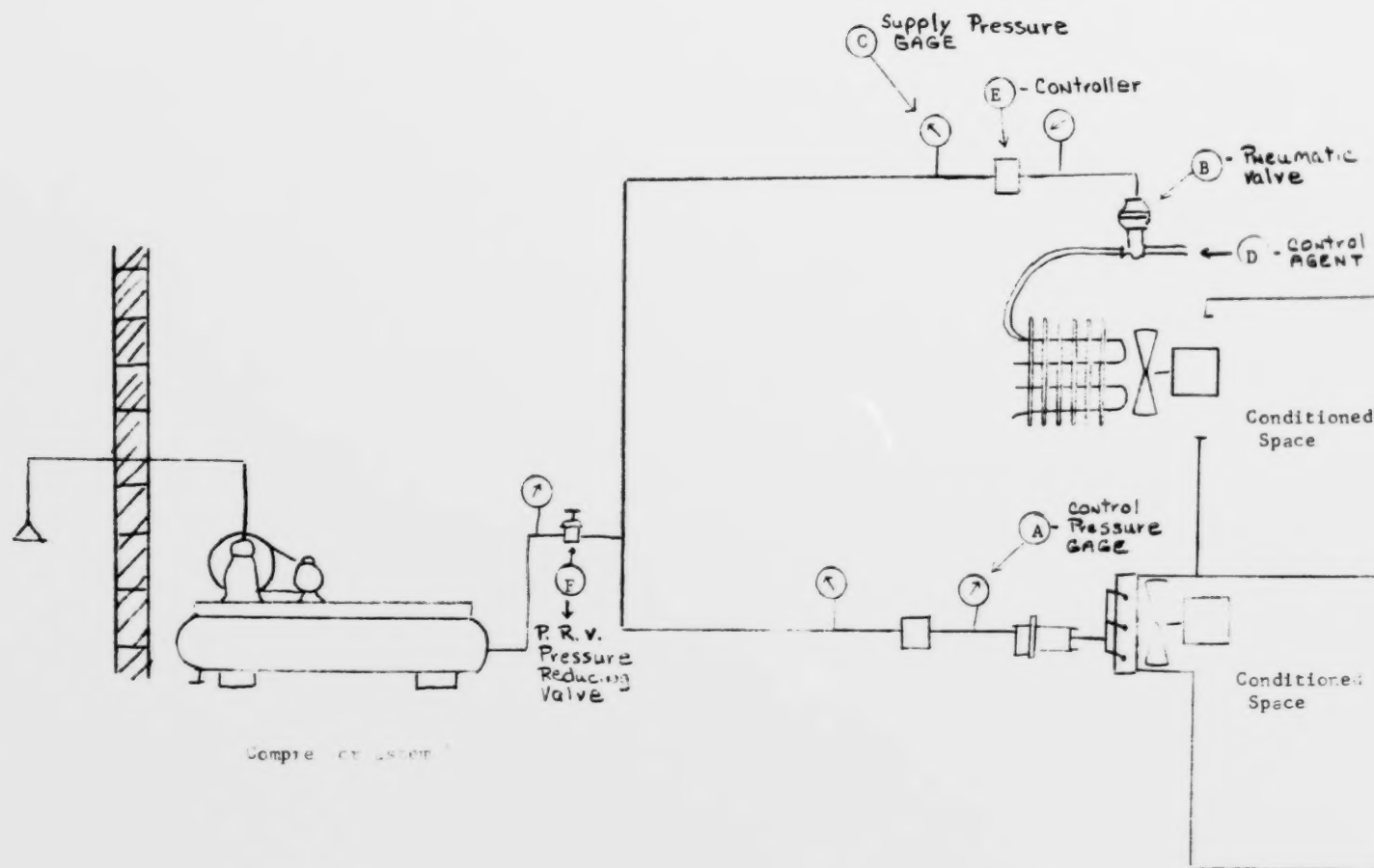
Refer to Figure 4 and answer the following questions.

1. Which lettered component will indicate supply pressure?
2. Which lettered component will indicate control pressure?
3. Which lettered component indicates a controlled device?
4. Where in the Figure would the control agent be located?

Refer to the following definitions and Figure 5, fill in the blanks with the numbers in Figure 5 that correspond to the following definitions.

1. Desired value : What you want
2. Set Point: What you set the controller at
3. Control Point: What you get
4. Sensing Element: The part of a controller which measures a change in temp, pressure, humidity, and converts this change to movement.
5. Sensitivity: A comparison of the amount of change in control pressure for each change in temp, pressure, and humidity.

- | | |
|--------------------------------|-----------|
| 1. Set Point
Definition | No. _____ |
| 2. Desired Value
Definition | No. _____ |
| 3. Control Point
Definition | No. _____ |
| 4. Controller
Definition | No. _____ |



Pneumatic Control System. Figure 4

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5. Controlled Device
Definition

No. _____

6. Control Agent
Definition

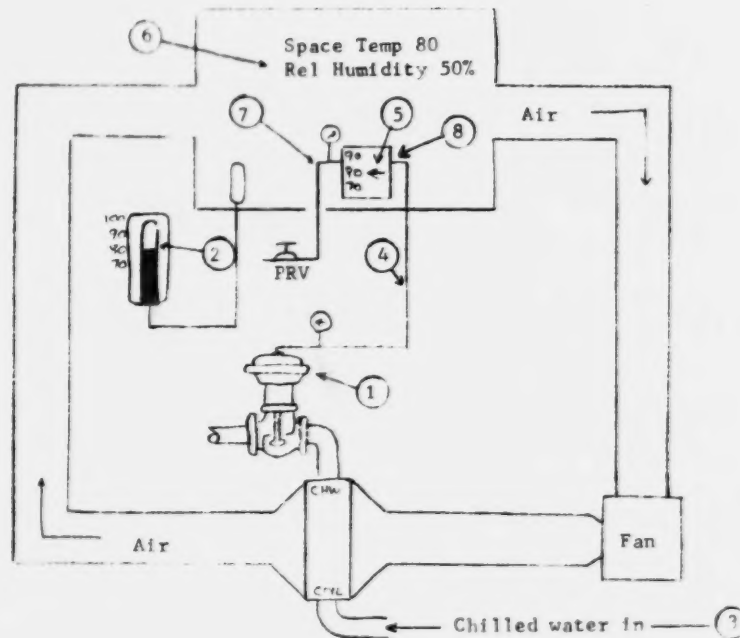
No. _____

7. Supply Line
Definition

No. _____

8. Control Line
Definition

No. _____



Control Loop. Figure 5

Read the following paragraphs answer the questions.

PNEUMATIC VALVES

The pneumatic valves are designed for precise regulation of water or steam flow through heating or cooling equipment in response to demand signals from a pneumatic controller. Valves are offered in a wide range of standard sizes and capacities to meet any requirements, and in a variety of body patterns and connections to allow flexibility of application. However, there are only three basic body styles and all patterns fall into one of these styles: normally-open (Figure 5), normally-closed (Figure 6), and three-way (Figures 7 and 8). The normally-open valve will close when air pressure from the controller is applied to the diaphragm. A normally-closed valve will open when the air pressure from the controller is applied to the diaphragm.

Figure 6



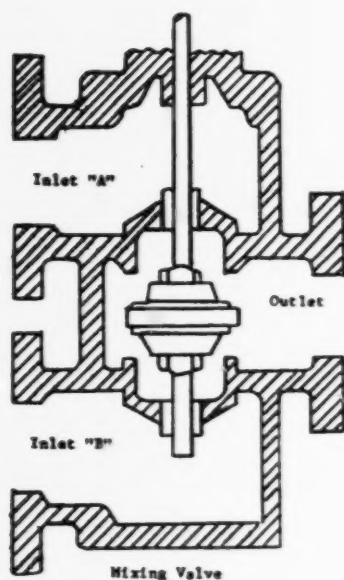
Normally-Open Valve

Figure 7

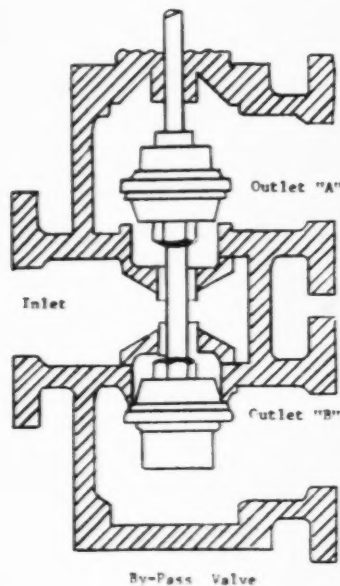


Normally-Closed valve

The third type is the three-way valve. This may be called a mixing, a diverting, or a bypass valve. There are three connections on this type, common, normally-open, and normally-closed. The mixing valve has two inlets and one common outlet. Air pressure from the controller regulates the inner valve so that the entire flow is from either one of the two inlets or a portion from both. Bypass or diverting valves have one inlet and two outlets. The flow is directed to either one of the two outlets when air pressure from the controller is applied to the valve operator. Any portion of the flow can be directed to both outlets by an intermediate air pressure in the operator.



Mixing Valve



By-Pass Valve

Figure 8.

Figure 9.

Operation of a Pneumatic Valve

In the operation of the pneumatic valve, air pressure from the controller enters the diaphragm chamber. The pressure rise in the chamber causes the diaphragm to push the plate down against the spring. The spring is compressed, and the valve disk or plug is moved against or away from the valve seat, depending on whether it is a normally open or normally closed valve.

1. What are three types of pneumatic valves?
2. What are two types of three-way valves?
3. How many inlets and outlets does a by-pass valve have?
4. What part in the valve holds the valve in its normal position (N.O. or N.C.)?

Read the following paragraphs answer the questions.

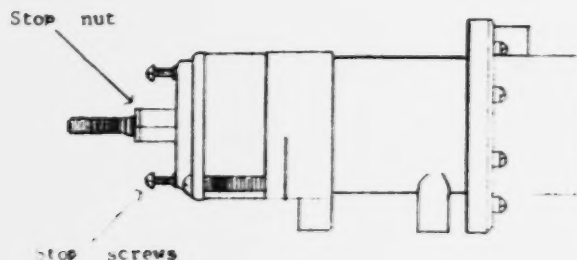
DAMPER OPERATORS

Damper operators are used to control dampers blades, which control the flow of air, its operation is similar to that of the pneumatic valve.

The majority of damper operators (Figure 10) are of the piston type. This operator has a long powerful straight stroke which requires no lever arrangements.

Air from the controller is applied to the molded diaphragm which has a positive seal to prevent leakage, (Figure 11). This air pressure expands the diaphragm forcing the piston and stem outward against the force of the spring. The movement of the piston varies proportionally with the air pressure applied to the diaphragm.

The spring returns the operator to its normal position when the air pressure is removed from the diaphragm.



Damper Operator

Figure 10

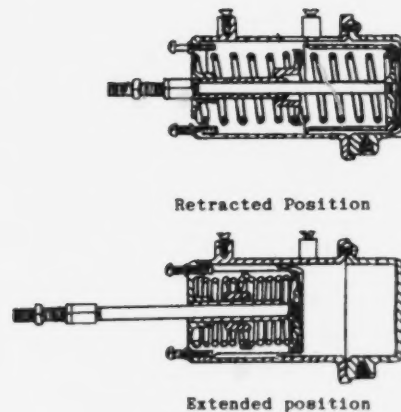


Figure 11

Adjustment

All sizes of piston type operators are provided with adjustable stops for limiting the stroke of the operator in the retracted position, as well as in the extended position. The latter is the position which the operator assumes when full air pressure is applied to it. When a piston type operator is attached to a damper or other controlled apparatus, it is very important that these stops be adjusted properly, as the incorrect adjustment of stops may cause damage to the damper operator or the damper, due to the great power of the piston type operator.

1. Dampers are used to control the flow of _____.
2. What is the position a damper operator assumes when full air pressure is applied?

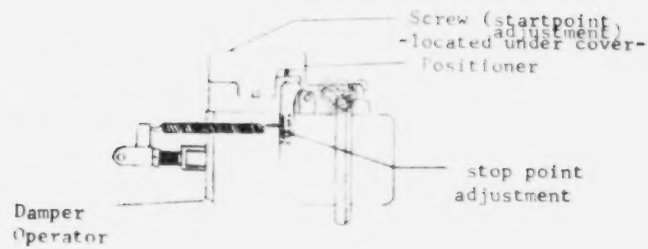
Read the following paragraphs and answer the questions.

POSITIONER

A positioner is an accessory added to a Controlled Device (CD)(Figure 12). It will accurately position the CD in the position demanded by the controller, and keep it in that position until the controller senses a change in variable.

Various conditions can cause inaccurate positioning of the CD. When these conditions exist, the controller cannot move the CD to the desired position. The controller sends the correct amount of pressure, but the resistance to movement keeps the CD from moving to the position wanted. The positioner will make the pneumatic CD go to the proper position.

The pneumatic damper can also have corrosion on damper linkages and opposition to movement due to airflow through the dampers which hamper the correct positioning of the damper. The positioner insures that the damper moves to the position called for by the controller.



Positioner being used on a Damper

Figure 12

1. What is the purpose of a positioner?
2. What are two conditions which hamper the correct positioning of a damper?
3. What are the two adjustments on a positioner?

STOP! You have completed the directed study to be completed prior to day 41 class.

Start here for the assignment to be finished in preparation for Day 42.

- a. Read the following paragraphs answer the questions.

ROOM THERMOSTATS (T-4002)

A room thermostat is a device that measures the temperature of an individual room. The thermostat converts the temperature changes into an air pressure (control pressure) that is sent to a controlled device (valve or damper). The controlled device regulates the flow of the control agent (chill water, hot water, steam, etc.) which will control the temperature.

The room thermostat can be used to automatically control the temperature for heating or cooling, but only one at a time. An application for cooling is shown in Figure 13. The room thermostat is installed on a wall where it will sense the temperature of the room. The room thermostat modulates the chilled water valve to control the temperature of the supply air. The room thermostat can be applied for heating as well as cooling.

The room thermostat has a sensing element (Bi-Metal Strip). When the room temperature increases, the element bends down and increases control pressure. When the room temperature goes down, the element bends up and decreases control pressure. The type of bi-metal strip will determine if the thermostat is direct or reverse acting.

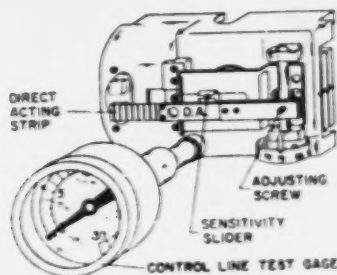


Figure 13

SENSITIVITY. The sensitivity should always be as high as possible without producing excessive hunting or cycling. The thermostat is factory set for approximately 2 1/2 psi per degree, but the sensitivity is adjustable between 1 and 8 psi per degree. Change the sensitivity, move the sensitivity slider.

1. What is the purpose of a thermostat in a pneumatic control system?
2. What determines the action of the thermostat?
3. What is the action of the thermostat when the sensing element bends down on an increase in temperature?

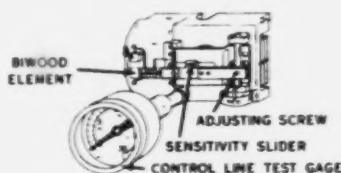
4. How is the sensitivity changed on the thermostat?

b. Read the following paragraphs answer the questions.

ROOM HUMIDISTAT

A room humidistat is a device that senses changes in relative humidity of an individual room. When a change occurs, the humidistat changes the control air pressure to the controlled device. The room humidistat can be used to automatically control the relative humidity for humidification or dehumidification, but only one or the other. It is installed on a wall where it will sense the humidity of the room and modulates the chilled water valve to control the relative humidity (moisture content) of the supply air.

Room Humidistat, H-4100 (see Figure 14).



Room Humidistat H-4100

Figure 14

Operation.

Direct Acting Humidistat: When the humidistat senses a rise in relative humidity the bi-wood strip bends down, this causes the control pressure to increase.

Reverse Acting Humidistat: When the humidistat senses a rise in relative humidity the bi-wood strip bends up, this causes the control pressure to decrease.

1. The controlled variable of _____ is sensed by the H-4100.
2. What type of sensing element is usually found in the H-4100?
3. When humidity changes the humidistat changes the _____ pressure.

Pneumatic Control Theory

c. Refer to Figures 15, 16, 17, and 18 as necessary to complete the following loops.

- | | |
|--|--|
| 1. AGENT: Hot Water
DEVICE: N.O. Valve
ACTION: _____ | 2. AGENT: Chilled Water
DEVICE: _____
ACTION: DA |
| 3. AGENT: Steam
DEVICE: _____
ACTION: RA | 4. AGENT: Chilled Water
DEVICE: N.O. Valve
ACTION: _____ |

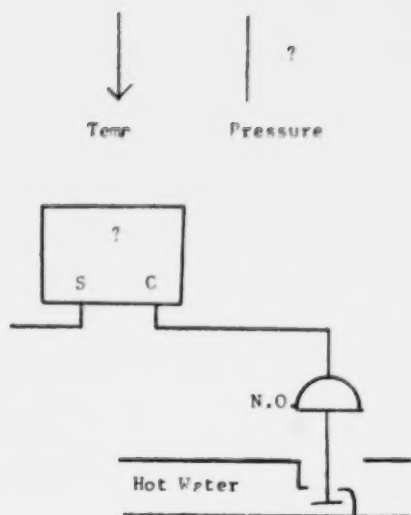


Figure 15

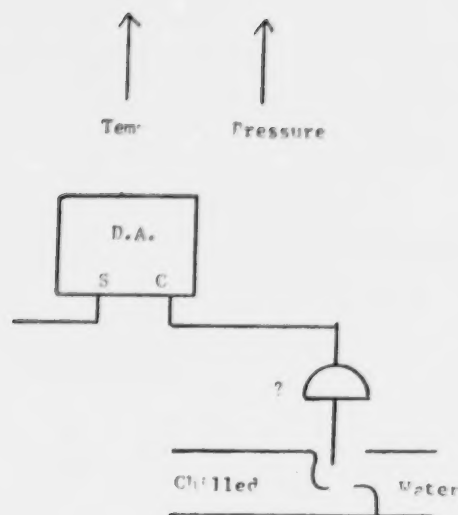


Figure 16

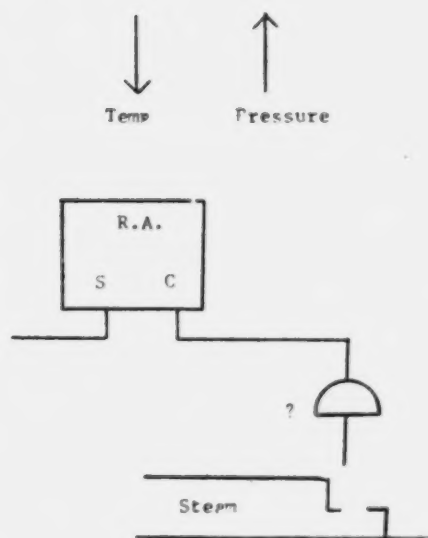


Figure 17

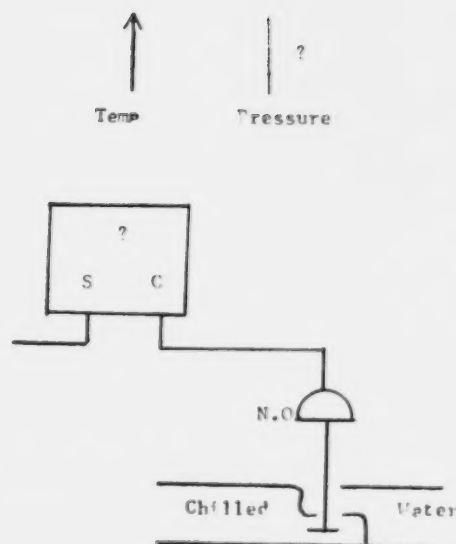
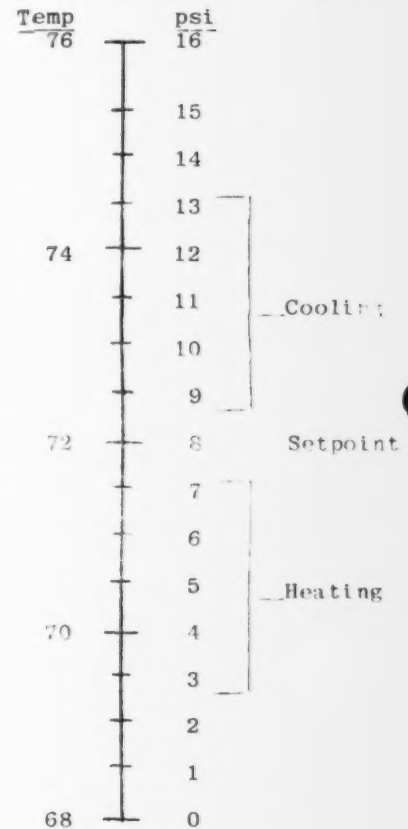


Figure 18

d. Refer to Figure 19 to answer following questions. A DA thermostat has two controlled devices. One is a NO Hot Water valve with a spring range of 3 psi to 7 psi. The other controlled device is a N.C. Chilled Water valve with a spring range of 9 psi to 13 psi. The thermostat has a sensitivity of 2 psi/1 degree, and the setpoint is 72 degrees.

1. When the temperature is at setpoint, what will be the position of the cooling valve? _____
The heating valve? _____
2. If room temperature increases to 75 degrees
 - what will the control pressure be? _____
 - what will be the position of the heating valve? _____
 - the position of the cooling valve? _____
3. At what temperature will the cooling valve be 1/2 open? _____
4. At what temperature will the heating valve be 1/2 open? _____
5. What is the throttling range of the cooling valve? _____
6. What is the throttling range of the heating valve? _____

- a. T/stat: DA
- b. Sensitivity: 2 psi/1 degree
- c. Heating valve
 - (1) Hot Water
 - (2) NO
 - (3) Spring Range: 3 psi to 7 psi
- d. Cooling Valve
 - (1) Chilled Water
 - (2) NO
 - (3) Spring Range 9 psi to 13 psi
- e. Setpoint: 74 degrees



d. Read the following paragraphs answer the questions.

Figure 19

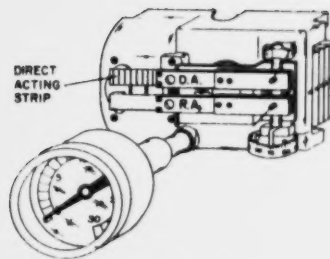


Figure 20

T-4752 HEATING-COOLING THERMOSTAT

The heating-cooling thermostat is a controller which measures the temperature of an individual room. The heating-cooling thermostat converts temperature changes into pressure changes in the same manner as the room thermostat. The heating-cooling thermostat is a combination of two room thermostats (a direct acting and a reverse acting) into one thermostat. In reality, it is a room thermostat that uses direct acting for control of heating in the winter and reverse acting for control of cooling in the summer. This controller can also be referred to as a summer-winter thermostat.

The heating-cooling thermostat can be used to automatically control the temperature for heating and cooling. The heating-cooling thermostat is installed on a wall where it will sense the temperature of the room. The controller modulates the controlled device to control the flow of chilled water in the summer and hot water in the winter.

Operation

The heating-cooling thermostat operates together with another controller sensing the outdoor temperature. When the outdoor temperature rises, the rise in temp is sensed by the outdoor T/Stat which will cause the heating-cooling T/Stat to be reverse acting for cooling. A decrease in temp sensed by the outdoor T/Stat will cause the heating cooling T/Stat to be direct acting and control the heating.

1. What is the action of the T-4752 controller?
2. The T-4752 uses _____ acting for heating and _____ acting for cooling.
3. The T-4752 controls a valve to use _____ water in the summer and _____ water in the winter.
4. Why is it necessary for the T-4752 to change its action?

- a. Read the following pages answer the questions.

LP 914 A (SENSOR)

There are four types of sensors; temperature, humidity, pressure, and dewpoint. Each can be used with the RP908A nonbleed controller. The temperature sensor, which we will work with, has an invar rod, brass rod, and a stainless steel lid. See Figure 21.

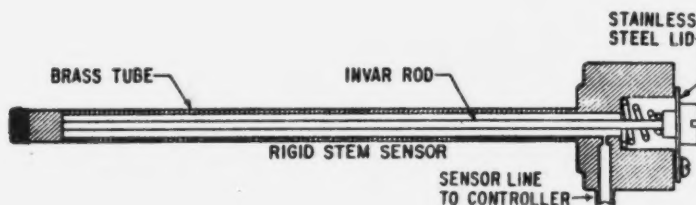
The sensor can be inserted into a duct or large water pipe in a remote area. It is connected to the controller by tubing.

OPERATION. On an increase in temperature the brass rod expands, moving the invar rod away from the lid. With the lid closed, the pressure will back up to the input chamber of the controller.

On a decrease in temperature the brass rod will contract, causing the invar rod to move the lid away from the seat. The movement of the lid is less than one ten-thousandths (.0001) of an inch. This will allow all pressure above 3 psi to escape to the atmosphere.

The sensor will operate accurately at a distance of 1000 feet or less.

The minimum signal of LP 914 a sensor is 3 psi at a sensed temperature of -40°F. The maximum signal is 15 psi at a sensed temperature of +160°. The sensor operating span is 200°.



LP914 Sensor

Figure 21

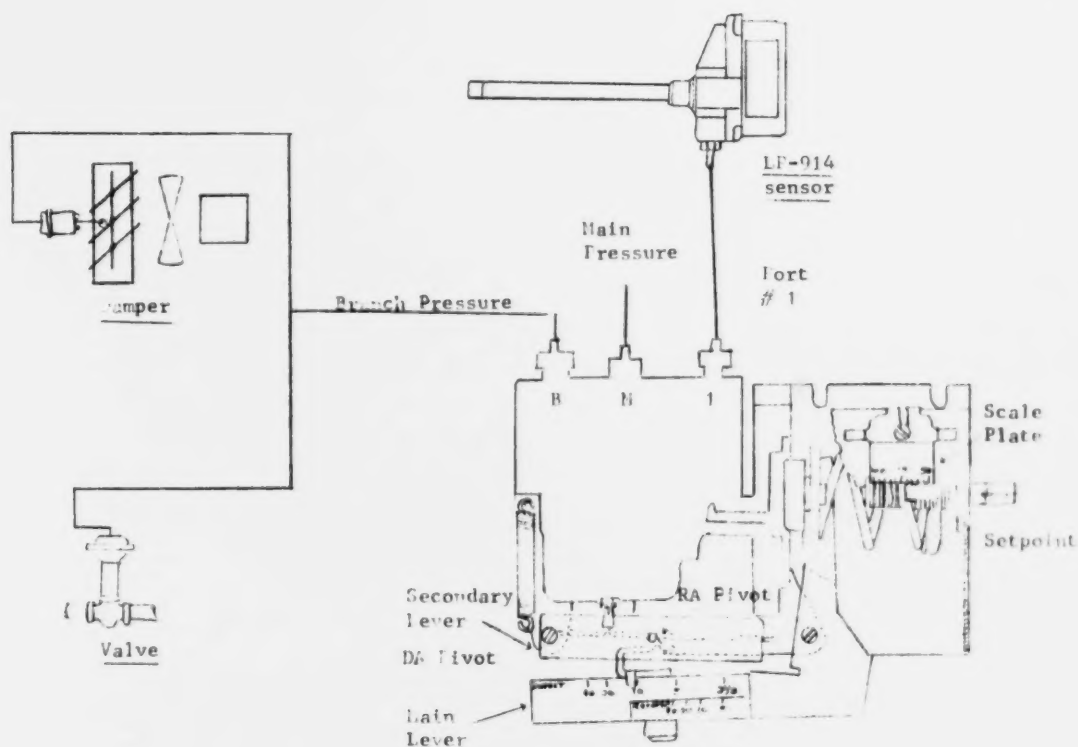
1. What are the four variables the RP908A is capable of controlling?
2. How is the sensor connected to a controller?
3. What is the minimum signal pressure sent to the controller from the sensor?
4. What is the sensor operating range?

b. Read the following paragraphs and answer the following questions.

RP-908A (controller)

The controller can be located in a remote equipment room or on a control panel. It is connected to the sensor by tubing and takes a small pressure change from the sensor and amplifies it through the main lever, secondary lever, and the relay chamber to provide a 0 to max psig branch line pressure. See Figure 22.

The controller is equipped with three springs (see Figure 41). Two small springs are connected to the secondary lever if reverse action is desired or disconnected if direct action is desired. The large spring is used only when the proportional band adjustment is set at 15% or above. The action of the controller can be changed by moving the pivot points of the secondary lever.



RP-908A Controller

Figure 22

1. What type of response does the RP-908A produce?
2. What is the action of the RP-908A?

3. Can the action of the RP-908A be changed, if so how?

4. When must the proportional band spring be connected to the main lever?

c. Read the following paragraphs and service chart #1 and answer the following questions.

Calibrating a Pneumatic Controller

If a pneumatic control system is to work properly, it must be calibrated properly. Calibration is a procedure of manually setting the control pressure at a specific variable. Listed are the basic steps for calibration of pneumatic controller.

1. Determine ambient variable (temp, pressure, humidity).
2. Set the set point dial to sensed variable.
3. Adjust calibration screw located on controller to the mid spring range (M.S.R.) for controlled device.
4. Turn set point dial to what you want.

These four steps for calibrating a pneumatic controller, are the basic four steps for the calibration of all controllers.

Maintaining a Pneumatic Control System

If a complex pneumatic control system is expected to keep on operating correctly, certain maintenance practices must be performed. Since the pneumatic control system is composed of a number of major components we will discuss the maintenance required for each.

Compressor - was discussed in a previous section, most important maintenance practice is to open drain valves daily to remove moisture.

PRV - Check output pressure daily.

Pneumatic Controller - most times a defective controller, will be removed and replaced. The reason being the complexity and small air passage ways involved. In some cases the pneumatic controller can be taken apart and a plugged filter replaced. Isolate the controller make SURE the controller is defective before replacing it.

Damper Operator - A damper operator that binds or does not operate should be replaced. In some cases graphite can be used to temporarily prevent binding in an operator until a new one can be obtained. Remember to replace the operator with one of the same spring range as the one it replaced.

Valve - A valve that will not close or binds during operation should be replaced.

Linkage - should be checked whenever it is suspected of being out of adjustment. The damper blade should assume the mid position when M.S.R. pressure is applied to the damper operator.

Once a pneumatic system is "set up" only a small amount of maintenance will be required to keep it operating correctly. Unnecessary adjustment "tinkeritus" is the biggest enemy of a control system.

Trouble Shooting a Pneumatic Control System

Troubleshooting will be a daily task for a refrigeration specialist. Listed is a simple troubleshooting chart for a pneumatic control system.

Service Charts #1

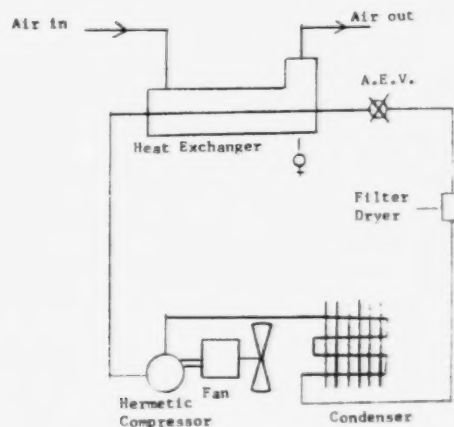
OBSERVATION	POSSIBLE TROUBLE	REMEDY
Compressor won't run.	1. Electrical Trouble a. No Power b. Blown Fuse c. Open Switch	a. Check Power b. Replace Fuse c. Close Switch
No or Low Supply Pressure	1. Inop Compressor 2. Plugged Supply Line 3. Leaking Supply Line 4. Prv Not Adjusted Correctly	1. Repair Compressor 2. Unplug Line 3. Fix Leak 4. Readjust Correctly
Supply Pressure Too High	1. PRV not Adjusted Correctly	1. Readjust Correctly
Control Pressure Not Correct	1. Controller Out of Calibration 2. Defective Controller	1. Recalibrate controller to MSR 2. Replace Controller
Control device will not go to position demanded by controller	1. Positioner (if used) out of adjustment 2. Control Device Binding	1. Readjust Positioner 2. Repair or Replace Control Device
Inaccurate position of valve or damper assy.	1. Linkage out of adjustment	1. Readjust Linkage

1. What is the first step of calibration of any pneumatic controller?
2. What is the calibration screw adjusted to during calibration?
3. What would be the possible trouble if the supply pressure was too high?
4. What is the possible trouble when the compressor won't run?
5. What should the linkage of pneumatic damper be adjusted to?

MECHANICAL AIR DRIER

The refrigerated air dryer provides continuous operation for supplying dry air for Pneumatic Control Systems. It does this by simply using a tube-n-tube evaporator. The refrigerant is in the inner tube and air in the outer tube. The refrigerant cools the air down, causing the moisture in the air to (condensate) thus removing the

moisture. This is (DEW POINT) important for smooth operation of controls. The unit's major components are: hermetically sealed compressor, using refrigerant, condenser fin and tube type, condenser fan, filter dryer (refrigerant type installed in liquid line), Heat Exchanger (tube-in-tube) AEV (automatic expansion valve), evaporator, automatic drain valve, by-pass valves, oil filter with automatic drain, high and low pressure air gages, pressure relief valve, high and low pressure outlet lines, and last but not least an inlet air line from compressor. Also, most units have pressure by-pass valves. These valves simply isolate the heat exchanger for easy maintenance. These valves are manually operated. Advantage is, it can be done without interrupting the control air supply. Automatic drain valves bleed off moisture from the system.



Mechanical Air Dryer
Figure 23

QUESTIONS:

1. What is a Refrigerated Air dryer?
2. How does this unit dry the air?
3. Why is dry air important?
4. What are the major components of the Refrigerated Air dryer?
5. What type of refrigerant is used?

6. What type of compressor does this unit have?
7. Explain the purpose of the heat exchanger.
8. Why does this unit need automatic drain valves?
9. What is used to meter refrigerant into the tube-n-tube counterflow air dryer?

STOP! You have completed assignment to be completed prior to Day 42 class.

Start here for Directed Study Assignment to be completed prior to day 43 class.

ELECTRICAL CONTROLS

OBJECTIVE

- * To develop a knowledge and understanding of electric controls, their use, advantages, and applications.
- * To develop the skills necessary for the installation, calibration, and maintenance of series 40, 80, and 90 electric control loops.

INTRODUCTION

To a large degree, the type of energy which is best suited for a particular control problem determines the kind of control equipment selected. Electrical energy is commonly used to transmit the controller measurement of a change in a controlled variable to other parts of the system. It also translates that measurement into work at the final control elements. For this purpose electricity has the following advantages:

- o It is readily available.
- o Electrical wiring is usually simple and easy to install.
- o Electrical energy readily amplifies the relatively small signal received by the sensing element making it possible to control systems which ordinarily could not be controlled.
- o The impulse received from the sensing element can be applied directly to produce one or several combinations or sequences in electrical outputs.

Assignment to be accomplished in preparation for day 43.

Read the following paragraph refer to Figure 13 and Figure 14 to answer the following questions.

SERIES 40-80 CONTROL CIRCUIT

The purpose of series 40-80 control loop is to control temperature, pressure, or humidity "Electrically".

Series -40 and -80 controllers include the following: room thermostats, insertion thermostats, pressure controllers and humidity controllers.

The series -40 control circuit is a line voltage circuit and the series-80 is a low-voltage circuit. Both are switched directly by the SPST switching action of the series-40 or -80 controller. These controllers may have either contacts or mercury switches.

Application

The series 40-80 motor is connected mechanically to be valve or damper (see Figure 26).

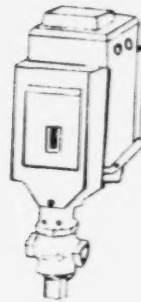


Figure 24

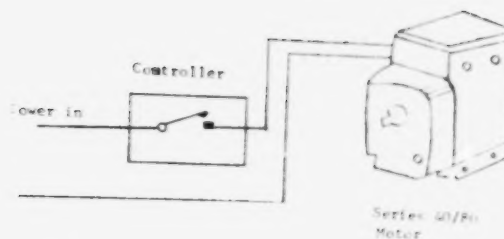


Figure 25

Operation

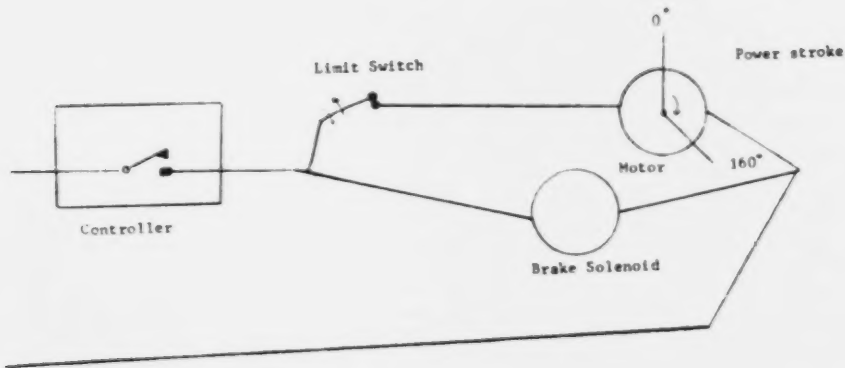
The controller (see Figure 25) contains a sensing element which senses a change in variable (temp, pressure, or humidity). This change in variable will cause the motor to be energized (motor runs) and de-energized (motor stops), by opening and closing contacts located in the controller.

1. Series 40/80 controllers can sense the variables of _____, _____, and _____.
2. What is the purpose of a series 40/80 control circuit?
3. What is the switching action of the series 40/80 controller?
4. What voltage is required for a series 40 motor? For a series 80 motor?

b. Read the following paragraphs, and Figure 25 answer the questions.

Operation of Series 40/80 Control Circuit

Figure 26 shows a simplified series 40-80 control circuit. It includes a controller, motor, limit switch, and brake solenoid. When the controller senses a change in variable (becomes unsatisfied), the contacts in controller close, causing the motor shaft to rotate. The shaft will now rotate slowly from the 0° (retracted) position, to the 160° (extended) position. When the shaft reaches the 160° position the limit switch opens, and the motor stops. The motor shaft is held in the 160° position by a brake solenoid. As long as the contacts are closed in the controller the brake is energized. When the variable changes (controller is satisfied), the contacts in the controller will open. The motor shaft now returns to the 0° position by using a failsafe spring.



Series 40 and 80 Control Circuit

Figure 26

1. What causes the contacts in the series 40/80 controller to open and close?
2. What is the purpose of a limit switch in the series 40/80 control circuit?
3. What is the purpose of the brake solenoid in the series 40/80 control circuit?
4. When is the series 40 and 80 brake solenoid energized?

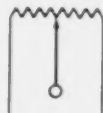
Read the following paragraphs and answer the questions.

Series 90 Control Circuit

The purpose of series 90 control circuit is to control temp, pressure, humidity. Unlike the series 40/80 this circuit operates to position the controlled device at any point between fully open and fully closed, including fully open and fully closed.

Series 90 Signal Potentiometer

The series 90 controller has a signal potentiometer which is a type of variable resistor. See Figure 27. The signal potentiometer is located in the controller, and changes its resistance with a change in variable (temp, pressure, or humidity).



Potentiometer

Figure 27

Series 90 Balancing Potentiometer

The series 90 motor has a balancing potentiometer, which is also a type of variable resistor. The balancing potentiometer is located in the motor, and changes its resistance with a change in the position of the motor shaft.

1. What is the purpose of a series 90 control circuit?
 2. Which control circuit will give the most accurate control of a variable series 40/80, or series 90? Explain why.
 3. What causes the signal potentiometer to change its resistance?
 4. What causes the balancing potentiometer to change its resistance?
- c. Read the following paragraphs and using Figure 23 answer the following questions.

SERIES 90 MOTOR

The series 90 motor will operate in both directions. The motor is started, stopped, and operated in both directions by a SPDT switch.

Operation

See Figure 28. When power (24 volts) is applied to the signal potentiometer current flows to the balancing potentiometer. The current flowing to the balancing potentiometer changes with changes in the variable. Refer to Figure 28 changes in current thru coil #1 and coil #2 will change the magnet strength of these coils and the operation of the SPDT switch. The operation of the SPDT switch will determine the direction of rotation of the motor.

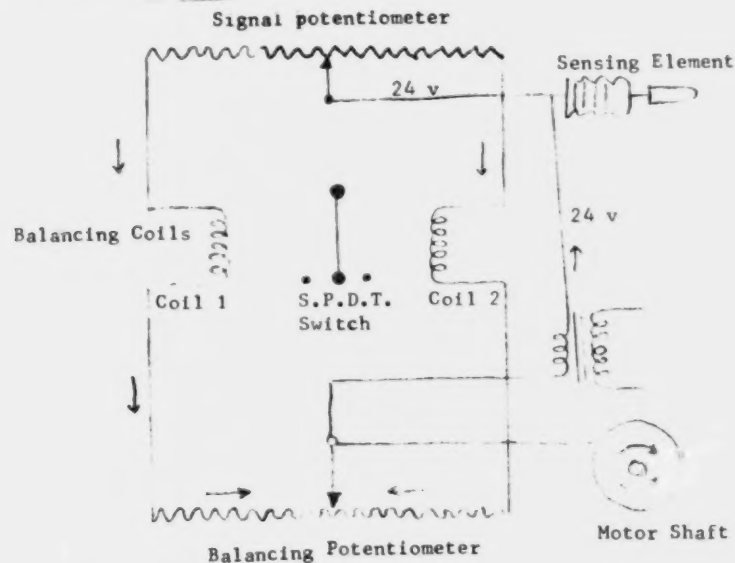


Figure 28

1. The series 90 motor will operate in _____ directions.
2. What does the SPDT switch do in a series 90 circuit?
3. What causes current flow to change in a series 90 circuit?
4. What is the voltage required on the series 90 control system?

Read the following paragraphs, and service chart #2 answer the following questions.

Calibration of a electric control system will be an important part of your job. Listed is the calibration procedure for a electrical control system.

1. Bring conditioned space to set point.
2. Center signal wiper arm located in controller visually.
3. Center signal wiper arm using ohmmeter (isolate controller).
4. Balancing wiper arm located in motor will balance automatically.

Listed is a service chart for troubleshooting. Read service chart #2, for troubleshooting of a electrical control system and answer the questions.

SERVICE CHART #2

OBSERVATION	POSSIBLE TROUBLE	REMEDY
Motor won't run	a. Electrical Trouble	
	1. No or Low Power	1. Check Power
	2. Blown Fuse	2. Replace Fuse
	3. Burned Transformer	3. Replace Transformer
	4. Burned Motor	4. Replace motor
	5. Bad Capacitor	5. Replace capacitor
	6. Dirty Potentiometer	6. Clean Potentiometer
	7. Loose or Broken Wire	7. Connect or Replace Wire
Innaccurate Control of Motor	1. Controller out of Calibration	1. Recalibrate Controller
	2. Defective Controller	2. Replace Controller
Inaccuracte Position of Valve or Damper Assy.	1. Linkage out of adjustment	1. Readjust Linkage

1. What is the first step for calibrating an electrical control system?
2. What instrument is used to center the signal wiper arm?
3. Name five possible troubles that would cause the motor not to run?
4. What is the most probable trouble when inaccurate position of control device is suspected?

Listed are the seven steps for replacing of an electrical control. Remember to replace the electrical control with one of the same resistance.

Steps for Replacing an Electrical Control

1. Remove all jewelry, observe all safety precautions.
2. Remove all power from circuit.
3. Check for loose, frayed, or corroded connections.
4. Replace electric control.
5. Apply Power.
6. Check for proper operation.
7. Calibrate only if necessary.

STOP! You have completed the Directed Study to be accomplished prior to day 43.

ELECTRONIC CONTROLS

OBJECTIVE

This section will aid you in learning electronics as applied to refrigeration and air-conditioning control systems.

INTRODUCTION

Electronic controls are being used more each day. Temperature, pressure, and humidity can be controlled electronically. The main components of an electronic circuit are semiconductors.

You will be required to inspect, adjust, troubleshoot and replace electronic controls. To do this you must know the construction characteristics, operating principles, and limitations of solid state semiconductors.

Start here for the Directed Study Assignment to be accomplished prior to day 44 class.

Read the following paragraphs and answer the questions.

Current flow through electronic components - to begin this section, a brief review of the atom is necessary. An atom consists of a positive charged nucleus around which spins negative charged electrons. These electrons travel around the nucleus in paths called shells. Because of the attraction of the unlike charges of the nucleus and electrons, the electrons are pulled toward the nucleus. The orbital electron has, as a result of its motion and velocity, kinetic energy that pulls the electron away from the nucleus. When the force between the unlike charges is equal to the force of the kinetic energy, the electron will assume a constant orbit around the nucleus of the atom.

1. What is the potential charge of the nucleus of an atom? _____

2. What is the potential charge of the orbiting electrons? _____

3. Because of their great orbital speed, electrons tend to break away from their orbit. What keeps the electrons in their orbit? _____

4. The electrons travel around the nucleus in paths. What are these paths called? _____

Not all electrons rotate the same orbital shell. The electrons are distributed to different orbital paths or shells according to the energy level of the electron. The outermost shell is called the valance shell, and the electrons in this shell are called valance electrons. The electrons in the valance shell are influenced the least by the attraction of the nucleus so the valance electrons are most easily moved out of their shell. When a valance electron is free of its shell it is called a free electron. The travel of free electrons is called current. The loss of an electron from the valance shell causes a vacancy in the atom. This vacancy is called a hole and causes the parent atom to become positive. The positive charged atom will attract an electron from the valance shell of a neighboring atom. When the hole in the parent atom is filled with an electron from a neighboring atom, the hole moved from the parent atom to the neighboring atom. You can see that current flow is the flow of electrons from negative to positive, and at the same time, the flow of holes from positive to negative.

1. What is the outermost shell of an atom called? _____

2. Describe a free electron. _____

3. Describe how a hole is formed. _____

4. What is the electrical potential of a hole? _____
5. What is the electrical potential of an electron? _____
6. Describe how holes move. _____

7. Explain current as it relates to the flow of electrons and holes _____

Substances that have a large number of free electrons are called conductors (copper, gold, silver). Substances with few free electrons are called poor conductors or insulators (rubber, glass, dry wood). Substances between conductors and insulators are called semiconductors (Germanium and silicon). Most solid state electronic devices are made from semiconductors.

Give two examples of semiconductors. _____

Crystals With Impurities

Pure germanium and silicon crystals are of no use as a semiconductor device because of the small number of current carriers available. However, when certain impurities are added to the crystal, the number of carriers can be increased to obtain a useful current. This process of adding impurities to the crystal structure is called DOPING. The added impurities create either an excess of electrons or an excess of holes, depending on the type of impurity added.

When arsenic is added to germanium, the arsenic atom will form bonds with the germanium atoms. The arsenic atom has five valence electrons in its outer shell, but uses only four of them to form bonds in the valence band with the germanium atoms. This leaves one electron to become a free electron. This impurity donates one electron to increase the number of free electrons without increasing the number of holes. Because the impurity donated free electrons to the semiconductor material, it is often referred to as a DONOR impurity. The resulting material conducts by electron movement and is called NEGATIVE CARRIER or N-TYPE semiconductor material. The amount of the impurity added is very small. The more impurity added, the more free electrons in the crystal.

An impurity having three valence electrons can be added to pure germanium to "dope" the material. Indium has three valence electrons; therefore it has one electron less than it needs to bond with the neighboring atoms. Therefore, an incomplete bond (hole) is created. Because this impurity created a hole which will accept one electron to complete the bond, it is called an ACCEPTOR IMPURITY. Acceptor impurities are added to a crystal to increase the number of holes without increasing the number of free electrons. The resulting material conducts by hole movement and is called POSITIVE CARRIER or P-TYPE semiconductor material. Thus, a hole is actually a positive mobile charge and exists in the valence band.

1. Explain why pure germanium or silicon crystals are of no use as a semiconductor device.

2. Name the process of adding impurities to germanium or silicon crystals.

3. Describe how donor impurities changes the germanium or silicon crystal.

4. Describe how acceptor impurities changes the germanium or silicon crystal.

Current Carriers in N- and P- Type Materials

Both electrons and holes are current carriers in semiconductors. Electrons are negative current carriers, and holes are positive current carriers. Current carriers are also referred to as MAJORITY carriers and MINORITY carriers. Majority current carriers are produced by doping. Minority current carriers are produced by applying energy (heat, light, etc.) to the semiconductor. In N-type material, electrons are the majority carriers. Then energy is applied to N-type material, ELECTRON-HOLE pairs are generated. The electrons add to the majority current carriers and the holes become the minority current carriers. In P-type material, holes are the majority carriers. Applied energy generates electron hole pairs. The holes add to the majority carriers and the electrons become the minority carriers. The number of minority carriers in both the N- and P-type materials is small when compared to the number of majority current carriers. As you recall from a previous discussion, this creation of an electron and a hole (electron-hole pair generation) is due to the amount of energy applied to the crystal. Therefore, the greater the amount of energy, the greater the number of minority and majority carriers. This energy is generally in the form of heat.

Current Flow in N-Type Material

Current flow in N-type material is illustrated in Figure 29. Conduction in this type of semiconductor is due to electron flow. The application of voltage across the material will cause the electrons to move through the crystal as shown. The positive potential will attract free electrons which leave the crystal and flow into the positive terminal of the battery. As an electron leaves the crystal, an electron from the negative terminal of the battery will enter the crystal, thus completing the current path. The majority current carriers in the N-type material are electrons. They are repelled by the negative side of the battery and move through the crystal toward the positive terminal.

Current Flow in P-Type Material

Current flow through P-type material is illustrated in Figure 30. Conduction in this material is by hole flow. The holes move from the positive terminal to the negative terminal of the P-type material. Electrons from the external circuit enter the negative terminal and fill holes in the vicinity of the terminal. At the positive terminal, electrons are removed from the covalent bonds, thus creating new holes. This process continues as the steady stream of holes (hole current) moves toward the negative terminal.

In both N-type and P-type materials, current flow in the external circuit consists of electrons moving out of the negative terminal of the battery and into the positive terminal of the battery.

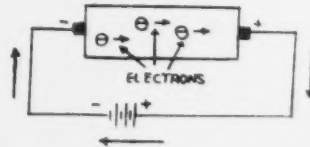


Figure 29. Current Flow in N-Type Material

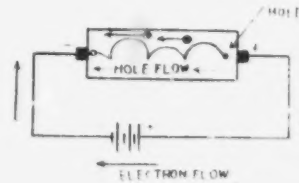


Figure 30. Current Flow in P-Type Material

1. Explain how majority and minority carriers are produced. _____

2. What are the majority carriers in N-type material? _____

3. What are the majority carriers in P-type material? _____

4. What is the direction of travel of the majority carriers in N-type material? _____

5. What is the direction of travel of the majority carriers in P-type material? _____

Read the following paragraphs answer the following questions.

Junction Transistor

The transistor is another electronic device that makes use of the flow of current carriers through a semiconductor the junction transistor has three elements and two P-N junctions. The three elements are: (1) the emitter, which gives off or "emit" current carriers; (2) the base which controls the flow of the current carriers; and (3) the collector, which collects the current carriers. A metal lead or contact is attached to each element or section, to allow the transistor to be connected to external circuitry.

Transistors have two P-N junctions. One P-N junction is between the emitter and the base; the other P-N junction is between the collector and the base. Current flow thru a junction transistor is illustrated in Figure 35.

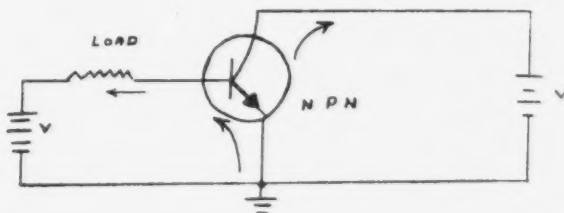


Figure 35

The transistor in Figure 35 contains a diode. Since current flows against the arrow it is easy to trace the flow thru this circuit.

1. What does a transistor make use of? _____

2. Name the three elements of a transistor. _____

3. How many P-N junctions does a transistor have? _____

Read the following paragraphs and answer the following questions.

NPN and PNP Transistors

Transistors are classed as PNP or NPN according to the arrangement of the N and P materials. A NPN transistor is formed by introducing a thin region of P-type material between two regions of N-type material in a single crystal of germanium or silicon. By introducing a thin region of N-type material between two regions of P-type material a PNP transistor is formed. Current flow thru a PNP and NPN transistor is illustrated in Figure 36 and Figure 37.

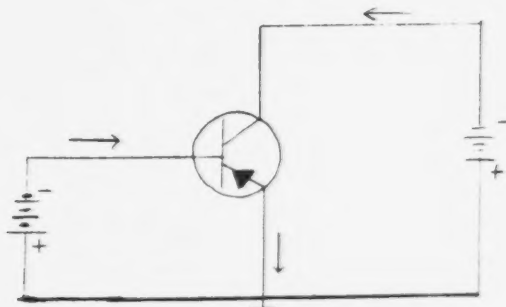


Figure 36. Current Flow Thru a PNP Transistor

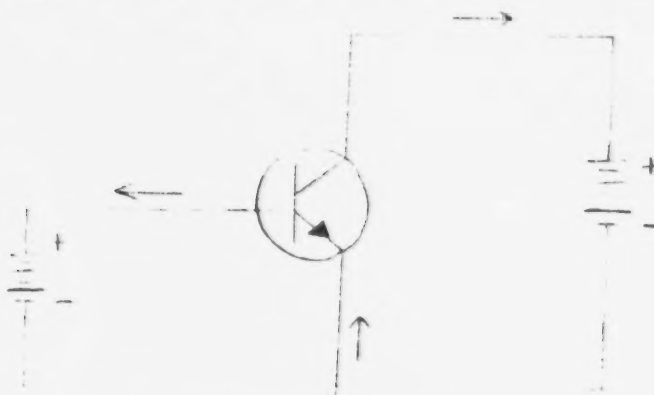


Figure 37. Current Flow Thru a NPN Transistor

1. How are transistors classified.
2. Name two types of transistors.

3. What material is the single crystal made of.

4. This single crystal of material would be known as a _____.

Read the following paragraphs answer the following questions.

Function of Bridge Circuit

The function of a bridge circuit is to sense a change in the controlled variable, make a motor (S-90) operate, change the position of a valve or damper. This regulates a control agent, which will change the controlled variable.

Previously this was done pneumatically and electrically. Whether we like it or not electronics is the "thing" of the future. Some of the advantages to electronics when compared to other methods of controlling a variable are:

- Long Life
- Reliability
- Speed of Response
- Smaller Size
- Ruggedness
- Less Heat Generated
- Reduced Cost of Operation

The term "solid state" is applied to semiconducting devices because they are "solid". They are made of crystalline substances, so they do not contain filaments, glass enclosures or rare gases, as tubes DO.

We first discuss the bridge rectifier since its supplies the source of power for the bridge circuit.

1. What is the function of the bridge circuit? _____

2. What are four advantages of electronics compared to previous loops? _____

- a. _____
- b. _____
- c. _____
- d. _____

3. Define solid state. _____

Read the following paragraphs and answer the following questions.

Operation of a Bridge Rectifier

A special source of power is needed for a electronic bridge circuit the purpose of a bridge rectifier is to supply full wave DC current to a bridge circuit. Figure 38 illustrates a bridge rectifier. The operation of the bridge rectifier, uses four P-N junction diodes wired as in Figure 38. Current can flow only in one direction thru a diode.

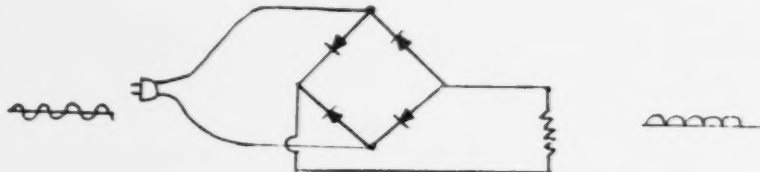


Figure 38

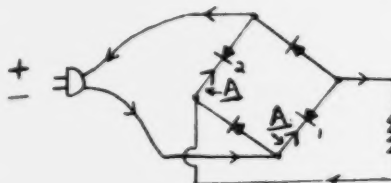
Remember:

AC flows in two directions.

DC flows in only one direction.

Figure 39 and Figure 40 shows the flow of current thru the circuit for each alternation of the AC cycle with 60 cycle current, this change in direction of current will change each 1/120th of a second. Remember current flows from - (neg) to + (pos).

AC in



1st Alternation
NOTE: Current flows through circuit A.

Figure 39

Note the Poles
have changed



DC out
2nd Alternation
NOTE: Current now flows through circuit B.

Figure 40

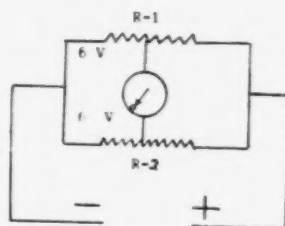
The bridge rectifier has changed AC to full wave DC.

1. What is the purpose of a bridge rectifier?
2. How many rectifiers does the bridge rectifier use for each alternation of AC current?
3. Could one diode be used to change AC to full wave DC? Why?

Read the following paragraphs and answer the following questions.

Operation of Bridge Circuits

When two resistors of the same value are wired in parallel and voltage is applied, no current will flow between the two resistors. This is illustrated in Figure 41.



Meter indicates no current flow across the bridge.

Figure 41

The brain of most electronic control loops is the bridge circuit. It is made up of one sensing element (T-1) that changes its resistance with a change in variable. It will also consist of three resistors (R1, R2, R4) of fixed resistance. See Figure 42.

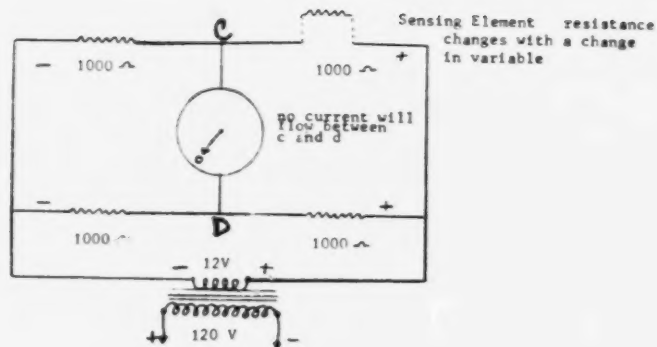


Figure 42

1. The "brain of" an electronic control loop is the _____.
2. The bridge circuit consists of sensing element that will change its _____ with a change in variable.
3. Is current flowing between points C and D in Figure 42? Explain.

Read the following paragraphs and refer to Figure 43 to answer following questions

Operation

With a change in temp around the sensing element (T-1) a change in resistance and voltage will take place between points C and D refer to Figure 43. For each degree of temp change resistance changes 2.2 OHMS, voltages changes .0085 volts.

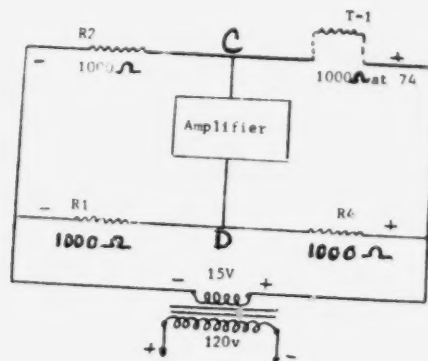


Figure 43

1. Using Figure 44 schematically connect a modified Honeywell Wheatstone Bridge. Indicate with arrows the direction of current flow.

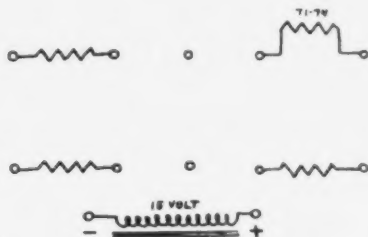


Figure 44

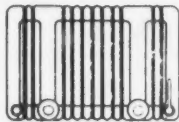
2. In your own words briefly explain how a modified Honeywell Wheatstone Bridge functions.

Read the following paragraphs and answer the following questions.

Sensing Elements

To be able to sense these changes in variable special types of sensing elements will have to be used in the electronic bridge circuit. These sensing elements will act like a variable resistor, by changing resistance with a change in variable two of the sensing elements for sensing temp and humidity are discussed.

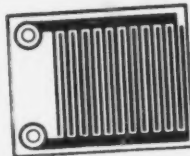
The sensing element of an electronic thermostat is a coil of balco wire wound on a bobbin, see Figure 45. Resistance thru this wire, changes directly with a temp change.



Sensing Element (Balco Wire)

Figure 45

The sensing element of electronic humidistat is a gold leaf grid embossed on a plastic base and covered with a special salt. Resistance thru this grid changes inversely with a humidity change. See Figure 46.



Sensing Element (Gold Leaf Grid)

Figure 46

Like a Pneumatic Control System the electronic control loop, must have a specific value (voltage, resistance, amperage) at a certain variable. When using balco wire the resistance is 1000 OHMS at 74°F. Resistance changes 2.2 OHMS, voltages changes .0085 volts per degree. If these specific values vary, inaccurate control of the variable (temperature) will result.

1. Sensing elements, sense a change in variable and change _____.
2. What type of sensing element is used to sense temp?
3. What type of sensing element is used to sense humidity?
4. When using balco wire how much does the resistance change for each 1°F temperature change?

Air conditioning control circuits use a variation of the bridge circuit, to control temperature and humidity in the conditioned space. The whole electronic control system now becomes quite complex by adding different circuits. The meter would be replaced by an amplifier circuit, which would be electrically connected to a discriminator, a motor, and a control device. Each of these "sections" of a electronic control loop all work together to control the final product "variable". Figure 47 illustrates the whole electronic control system. Each of the sections will be discussed at a later section.

Read the paragraphs that follow, answer the questions, and be prepared to discuss the information tomorrow in class.

This section deals with the application of electronic components as to electronic controls. Five components will be covered and you will be responsible to discuss them tomorrow in class. Covered in this section will be diodes, PNP transistors, NPN transistors, capacitors, and inductors.

The impedance (opposition to the flow of current) in an AC circuit may be partially made up of reactors. There are two different types of reactors --- inductors and capacitors. They do not dissipate electric energy in the form of heat as do resistors, but store energy and then deliver this energy back to the circuit. AC circuits may consist of various combinations of resistors and reactors.

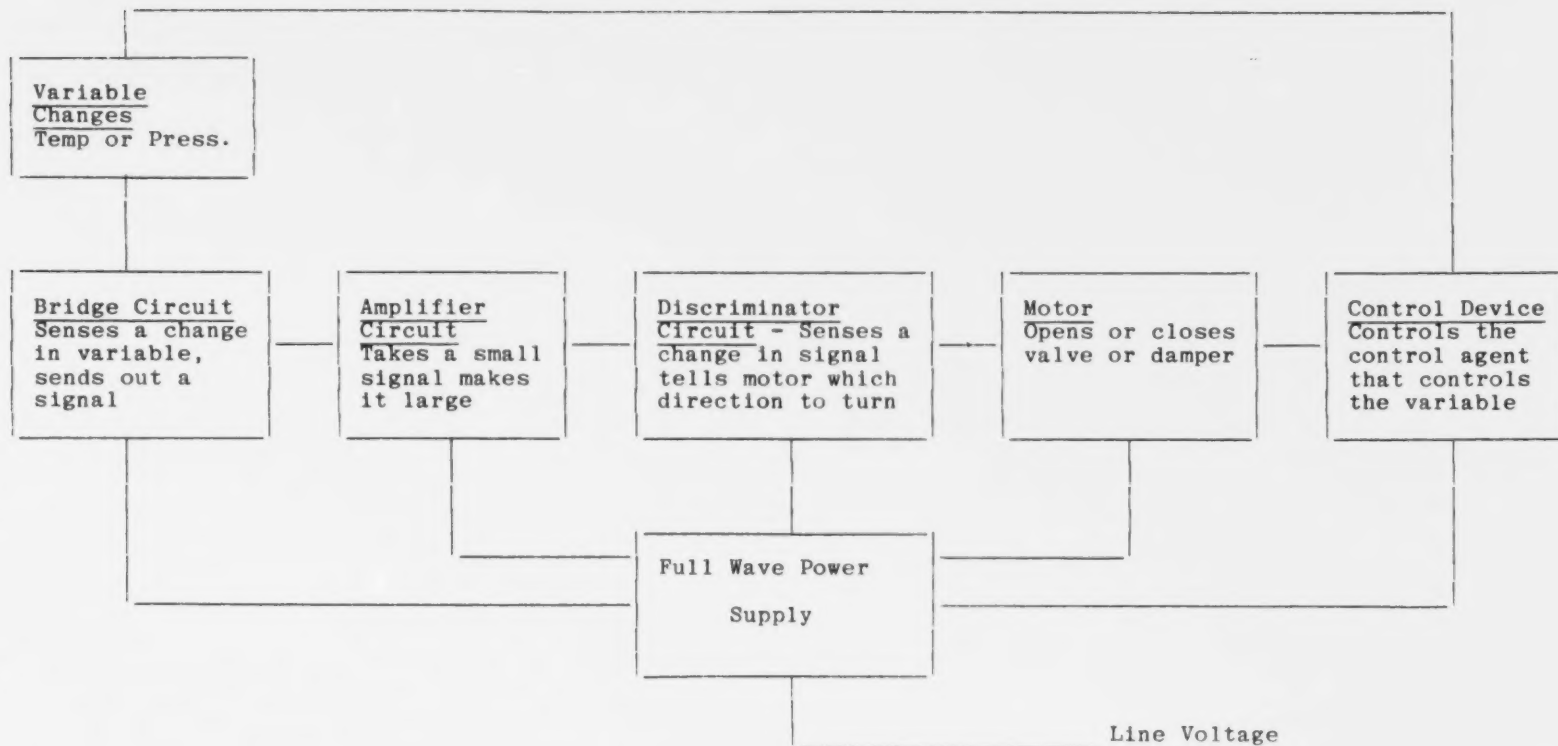


Figure 47
Operation of an Electronic Control Loop

1. Define circuit impedance. _____

2. How are resistors and reactors different? _____

3. How are resistors and reactors the same? _____

4. List the types of reactors. _____

Inductor - An inductor is an electronic component consisting of a number of turns of wire around a core. The core may be hollow or metal (soft iron). Inductance is defined as that property of a circuit which opposes any change in the rate of current flow. Some electronic equipment requires a source of direct current as well as alternating current. When the available power source is alternating current, some of the alternating current must be changed to direct current. In the process of converting from alternating current to direct current, it is necessary to rectify the alternating current, resulting in pulses of DC current. These pulses must be smoothed out to obtain a constant value of direct current. Since an inductor stores energy when the current flowing through it is increasing, and returns the energy to the circuit when the current is decreasing, it is used in smoothing out these pulses. Inductors used for this purpose are called filter chokes since they smooth out or choke out the variations in current.

1. Physically describe an inductor. _____

2. Define inductance. _____

3. Discuss the value of an inductor in a DC circuit. _____

4. What is an inductor called when it is used in a DC circuit? _____

The second type of reactor is the capacitor. The capacity for storing energy in an electric field is commonly called capacitance. When an alternating voltage is applied across a capacitor, the capacitor charges in one direction, discharges, and charges in the other direction, as the polarity of the alternating voltage changes. Even though electrons do not actually pass through the capacitor, there is a continuous flow of alternating current when a capacitor is connected in an alternating-current circuit. It can be said that a capacitor blocks the flow of direct current and is a conductor for alternating current. The electrolyte capacitor is used in DC filter circuits to help smooth out DC ripples or pulses. This type of capacitor has a large amount of capacitance for a relatively small size. These capacitors cannot be used as conductors for AC since one side of the capacitor must always remain positive in respect to the other. Otherwise the capacitor will be destroyed. Just as an Inductor maintains a constant rate of current flow in a DC circuit, capacitors will maintain a constant voltage.

1. Define Capacitance. _____

2. AC can pass through a capacitor, but DC cannot. True False (Circle one)

3. What type capacitor is used in DC circuits? _____

4. State the purpose of a capacitor in a DC circuit. _____

Diode - As you recall, the PN junction is used as a solid state diode (rectifier). It changes, or rectifies AC to pulsating DC. It is installed between an AC source of power, usually a transformer, and the DC load in an electronic circuit. The DC output from the diode is constantly changing in amplitude, being in the form of pulses.

What is the application of a diode in an electronic circuit? _____

Transistors - The PNP transistors, and the NPN transistors are current, voltage, or power amplifying devices. They are used in air conditioning electronic control circuits to amplify small voltage signals originating from a sensed change in temperature or humidity. Another application of the transistor is to detect if the voltage signal coming from the amplifier transistor is in or out of phase with the originating voltage, and by detecting the phase, rotate a series 90 electronic motor. The series 90 motor will regulate the flow of a control agent to bring the temperature or humidity back within desired limits.

1. In general, how are PNP and NPN transistors used in electronics? _____

2. What are the applications of transistors in the electronic phase detector control circuit?

STOP! You have completed the assignment to be completed prior to day 44.

Start here for the directed study assignment to be completed prior to day 45.

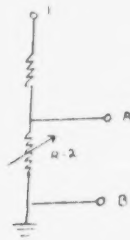
Read the following paragraphs and answer the following questions.

Purpose of Amplifiers

The purpose of amplifier is to make larger the signal that originates in the bridge. This signal that originates in the bridge is very small, and must be "boosted" up to a signal of sufficient strength to be able to be used.

Principles of Operation

When trying to learn the principle of operation of a transistor several principles must be considered. First: A change of resistance will cause a change in voltage. Second: Amplification depends on the change in the transistors resistance caused by an input signal.



DC Source Voltage

Figure 48

Figure 48 shows a voltage divider consisting of fixed resistor R-1 and variable resistor R-2 connected across a DC voltage source. The voltage at point A with respect to ground is determined by the size of the resistors and the applied voltage. Decreasing the resistance of R-2 causes the voltage at point A to decrease. Increasing the resistance causes the voltage at point A to increase. The resistance of R-2 provides a control of the voltage at point A.

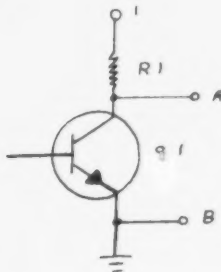


Figure 49

Figure 49 shows how a transistor then acts like a variable resistor. If base current is small the resistance of q1 would be large, and the voltage at point A would be almost equal to the applied voltage. If base current is a large value, the resistance of q1 would be small, and the voltage at point A would be almost equal to zero volts. The results is that a change in base current controls the voltage at point A.

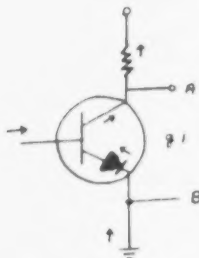


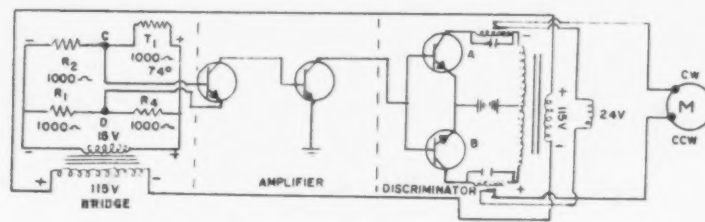
Figure 50

Figure 50 shows current flows thru a NPN transistor current always flows against the arrow of the P-N junction diode. It also flows from the emitter to the collector of the transistor. The base controls the flow of current carriers.

1. What is the purpose of an amplifier? _____

2. Will a change in resistance change voltage? Explain your answer. _____

The previous section discussed the application of electronic components in an air conditioning electronic control circuit. Electronic controls are gradually replacing some of the mechanical electric controls that are used to control the temperature or humidity in a conditioned space. This section will concern itself with a typical electronic control circuit called a phase detector circuit, see Figure 51. This circuit is composed of four main parts the bridge circuit, which contains a solid state thermostat or humidistat, senses a change in variable away from set point and sends a small corresponding voltage signal to the amplifier circuit. The amplifier circuit receives the small voltage signal sent from the bridge circuit, and relays a larger voltage signal to the discriminator circuit which includes two transistors. These transistors depending on whether the voltage signal received from the amplifier is in or out of phase with the originating voltage, will determine the rotation of an electronic series 90 motorized valve, or damper assembly.



Schematic of Bridge, Amplifier and Discriminator (Phase Detector) Circuit

Figure 51

For the sake of simplicity, many of the resistors and condensers are not shown in these diagrams.

The conditions when the discriminator transistors will conduct are:

- When collector is positive.
- When signal on base is positive. This is, on the positive alternation.

1. List the four parts of the phase detector circuit, and state the operating principle of each part.

a. _____

b. _____

c. _____

d. _____

2. What is the purpose of electronic controls?

3. Electronic controls are used to control _____ and _____
in a conditioned space.

Read the following paragraphs and answer the following questions.

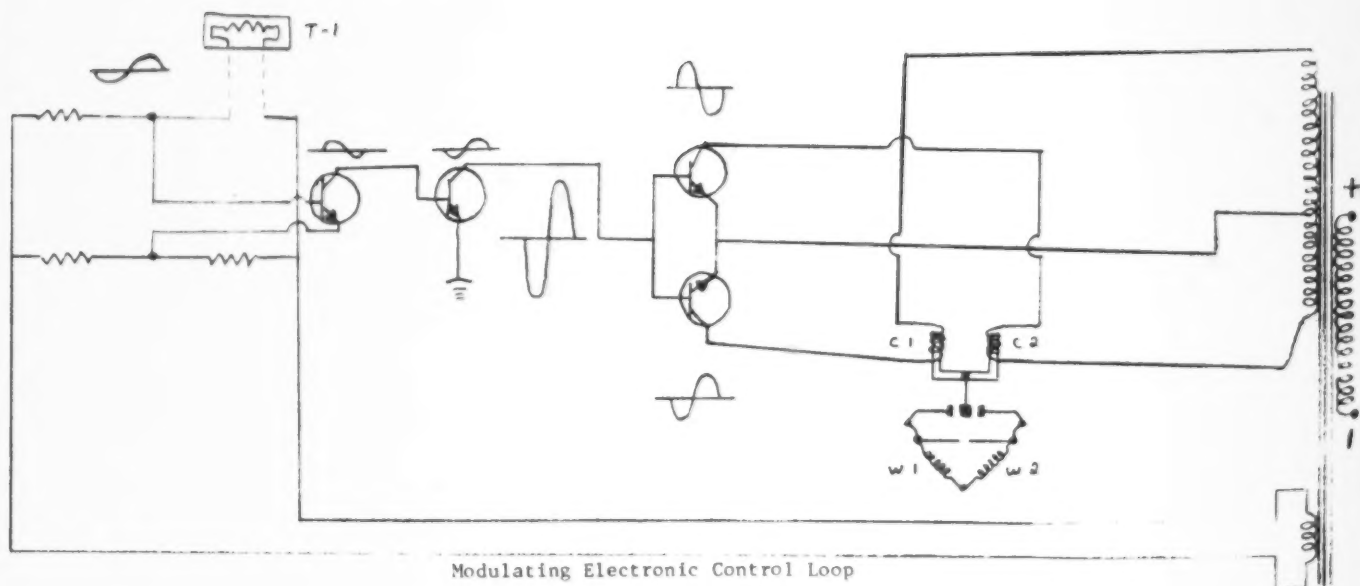
Operating Principle of Modulating Electronic Control Loops

A modulating electronic control loop will give like a proportional control loop, very precise control of the variable. The complete modulating circuit is shown in Figure 52. The circuit as previously discussed consists of a bridge, amplifier, discriminator, and motor circuit.

Operation - the resistance of T-1 (Balco Wire) decreases on a temperature fall, increases on a temperature rise. This rise or fall in variable, will cause an in or out phase to originate in the bridge circuit. This small signal will now be sent to the amplifier circuit, which builds up this small signal and makes it large. The amplifier will have two stages of amplification. Notice at the first stage of amplification the signal is 180° out of phase with the signal that originates in the bridge. Depending on the phase (which depends if the temp raised or lowered), will cause transistor T-1 or T-2 to allow current flow to C-1 or C-2. The coils will cause the motor to be energized and run depending on which coil is energized and will determine the direction of rotation of motor. Since this is now a modulating electronic control loop, small changes in variable, will cause small changes in the position of the motor shaft. The operation of a electronic control loop is very similar to a series 90 electric control loop.

1. The resistance of the balco wire (T-1) _____ on a temp fall, and _____ on a temp rise.
2. A rise or fall in temp will cause a _____ phase or _____ phase signal to originate in the bridge.
3. Why does the amplifier have two stages of amplification.

4. What will cause the motor to run clockwise or counter clockwise? _____



Modulating Electronic Control Loop

Figure 52

Read the following paragraphs.

Troubleshooting of an Electronic Control Loop

The electronic control loop works of electronical energy, just as an electric control loop does. Most of the trouble associated with the series 90 electric control loop will also apply to the electronic control loop.

No Power - Check source of power.

Opens - Ohmmeter would indicate infinity.

Shorts - Ohmmeter would indicate zero resistance.

Low Power - Dirty, loose, or corroded connections. Meter would indicate low voltage.

Replacing Electronic Controls

Many of the electronic controls, used out in the field, are too complex, and intricate to be field repairable. Listed below is a general procedure for the replacement of electronic controls.

1. Determine the electronic control is defective. Remember it should have a very specific value (resistance) at a certain variable.
2. If it has been determined the electronic control is defective remove all power from electronic control circuit.
3. Replace the electronic control with an identical controller. The electronic controller must be replaced, with an exact replacement since changes in resistance and voltages are so small.
4. Calibrate controller only if necessary.
5. Check for proper system operation.

Circuit analysis

Electronic controls operate with a precise change of resistance and voltage. With an exact variable change these values must be exact, to make the electronic system operate correctly.

Check the balco wire, it must have a resistance of 1000 OHMS at 74°F.

Check resistance change of balco wire. It must increase 2.2 OHMS for each 1°F temp increase.

Check voltage change of balco wire. It must change .0085 volts for each 1°F temp change.

Gold Lead Grid must have a resistance of 2000 OHMS - wet 95% RH 3 million OHMS - Dry 10% RH.

Adjustment Procedures

Adjusting an electronic control circuit, could become an important part of your job. The following steps are listed.

1. Determine around controller temperature.
2. Turn set point dial to temperature determined in step number one.
3. Check meter.
4. If current flows adjust control point adjuster, until meter zeros.
5. Current will now flow with a change in temperature, and not flow at set point.

Technical Training

Refrigeration and Cryogenics Specialist

AIR CONDITIONING CONTROLS



USAF TECHNICAL TRAINING SCHOOL
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

DESIGNED FOR ATC COURSE USE

DO NOT USE ON THE JOB

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Supersedes WBS J3ABR54530 001-IV-1 thru IV-6, Feb 1981

AIR COMPRESSOR EQUIPMENT

PART 1

OBJECTIVE

Given the information, state the types, purpose and operating principle of air compressing equipment used to support Air Conditioning Systems. 80% accuracy must be attained.

PROCEDURE

Using notes and material given, answer the following questions:

1. State the types of air compressing equipment used to support Air Conditioning Systems. _____

_____.
2. What purpose does the air compressing equipment serve in a Pneumatic Control System?

_____.
3. What purpose does the safety relief valve serve in the Air Compressing Assembly?

_____.
4. What purpose does the air compressor serve in the Air Compressing Assembly?

_____.
5. What purpose does the high pressure motor control serve in the Air Compressing Assembly? _____
6. What purpose does the pressure reducing valve serve in the Air Compressor Assembly?

_____.
7. At what component does air first enter the system?

_____.

8. What component changes ambient air pressure to high pressure air?

9. What component determines the pressure in the air storage tank?

10. State the operating principles of air compressing equipment.

PART 2

OBJECTIVE

Given a disordered list of steps necessary for the installation, replacement of defective parts, checking equipment operation, operator service, and maintenance of air compressing equipment, select the appropriate steps for each activity and place them in logical sequence. List must be completed with 90% accuracy.

PROCEDURE

Select appropriate steps and place them in logical order. Each step may be used only once.

I. Installation

- 1.
- 2.
- 3.
- 4.

II. Replacement of defective parts

- 1.
- 2.
- 3.

III. Checking equipment operation

- 1.
- 2.
- 3.

IV. Operator service and maintenance

1.

2.

3.

- a - Tanks drained each day
- b - Check for abnormal noises
- c - Remove all jewelry
- d - Select a location free from excessive dust and moisture with ample light and space for servicing
- e - Observe compressor for correct direction of rotation
- f - Air filter cleaned each 30 days
- g - Disconnect power to unit
- h - Check for leaks and overheating
- i - Replace defective part with replacement part
- j - Select a compressor of proper size and construction
- k - Check compressor for security of mounting, and valves for proper operation
- l - Oil changed each 500 operating hours
- m - Mount level with a substantial base, 12-18 inches from wall

PNEUMATIC CONTROLS

PART 1

OBJECTIVES

Given the information, explain the purpose, use, and operating principle of pneumatic controls with 80% accuracy.

PROCEDURE

Using notes and material given, answer the following questions:

1. What component determines the pressure in the supply line?

_____.

2. What determines the pressure in the control line? _____

_____.

3. What are three control agents? 1. _____, 2. _____
3. _____.

4. What term means the difference between set point and control point?

_____.

5. What is throttling range? _____

_____.

6. What is spring range? _____

_____.

7. What is sensitivity? _____

_____.

8. What is the action of a controller that decreases control pressure on a drop in measurable variable? _____

9. What is the action of a controller that decreases control pressure on a rise in measurable variable? _____

10. What is two-position response? _____

11. What is the range of control pressure for a proportional response controller? _____

12. Name three types of pneumatic controls used in air conditioning.

a. _____

b. _____

c. _____

13. What is the purpose of pneumatic controls? _____

14. What is the use of pneumatic controls? _____

15. What type sensing element is found on the T-4002 thermostat? _____

16. What causes the sensing element on the T-4002 to open or close the leakport to change the control pressure? _____

17. What is required to close a normally open pneumatic valve? _____

18. What would occur if you lost supply pressure to a controller? _____

19. What component determines the pressure in supply line? _____

20. What component determines the pressure in control line? _____

PART 2

OBJECTIVE

Working as a member of a team, and using refrigeration controls trainer, calibrate the pneumatic thermostat to maintain a temperature specified by the instructor $\pm 4^{\circ} \text{F}$.

PROCEDURE

Calibrate controller to maintain temp specified by instructor

CALIBRATION PROCEDURES

- CAUTION - remove all jewelry, observe all safety precautions

1. Connect flexible air line located in trainer to air supply located on wall behind trainer.
2. Turn on air valve located on wall.
3. Using a T-4002 thermostat, and a refrigeration controls trainer, connect lines as shown in Fig. 1.

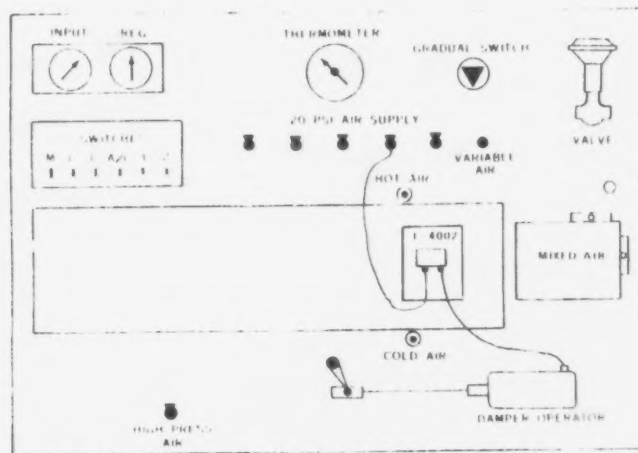


Figure 1

4. Apply 20 psi supply air to T-4002 thermostat.
Is the thermostat direct or reverse acting? _____
5. Determine ambient temp. _____
6. Set set point dial to ambient temp.
7. Adjust calibration screw to mid spring range of controlled device which will be specified by the instructor.
8. Turn dial to desired temperature.
9. turn on fan, heaters, and conditioner, observe response of controller.
10. Have instructor check your work.

PART 3

OBJECTIVE

Working as a team member, and using a refrigeration controls trainer, locate two of three instructor induced malfunctions. Maintain the pneumatic equipment by repairing the malfunctions with instructor assistance.

PROCEDURE

Repair the instructor induced malfunctions with instructor assistance, using service charts supplied.

1. Notify the instructor when you have located each malfunction.
2. Be prepared to inform the instructor of the corrective action required to repair the malfunction.

	OBSERVATION	TROUBLE SUSPECTED	REMEDY PERFORMED
#1			
#2			
#3			

SERVICE CHART

When troubleshooting exercise is completed:

- a. shut off air valve located on wall behind trainer.
- b. disconnect flexible air hose from air supply line located on wall.
- c. disconnect plastic lines from thermostat, put thermostat and plastic lines in proper place.

PART 4

OBJECTIVE

Given the information, state the operating principles of mechanical air dryers with no more than two errors.

1. Where does the mechanical air dryer get the compressed air that it dries?

2. How does the mechanical air dryer greatly reduce the temperature of the compressed air? _____

3. Why is it necessary to reduce the temperature of the compressed air?

4. Name the five main components of the mechanical air dryer.

- a. _____
b. _____
c. _____
d. _____
e. _____

5. What is the purpose of each of the five main components? _____

ELECTRICAL CONTROLS

PART 1

OBJECTIVE

Given the information, explain the purpose, use and operating principle of electrical controls with 80% accuracy.

PROCEDURE

Using notes and material given, answer the following questions.

1. What is the purpose of electrical controls? _____

_____.
2. What is the use of electrical controls? _____

_____.
3. The series 40 control circuit is supplied with _____ volts.
4. The series 80 control circuit is supplied with _____ volts and,
therefore, must use a _____ to reduce the power supply.
5. What is the response of a series 40/80 control circuit? _____

_____.
6. When the series 40/80 motor runs and the shaft rotates a _____
stops the motor at the 160° position.
7. Does the series 40/80 motor contain two limit switches? _____. Explain.

_____.

8. The _____ holds the shaft in the 160° position.
9. When is the brake solenoid energized? _____
10. The _____ returns the motor shaft to the 0° position.
11. The series 90 control circuit is supplied with _____ volts.
12. What is the response of a series 90 control circuit? _____
13. A change in _____ will cause the _____ circuit to become unbalanced.
14. What are the three electrical circuits in the series - 90 control loop?
- a. _____
 - b. _____
 - c. _____

Explain the function of each.

15. Does current flow through a balanced series - 90 bridge? _____ Explain.

16. What type motor is used in the series -90 control loop? _____

17. What controls the balancing relay in the series - 90 control loop?

18. What type switching action does the series 90 balancing relay contain?

19. The balancing wiper arm in the balancing potentiometer is directly connected to the

20. If the signal wiper arm in the series 90 controller became insulated from the resistor, what would be the result?

PART 2

CALIBRATION PROCEDURES

OBJECTIVE

Working as a member of a team and using a Refrigeration Controls Trainer, calibrate a series 90 electrical control loop with instruction assistance.

PROCEDURE

Using your workbook notes, calibrate a series 90 motor

CAUTION - Remove all jewelry, observe all safety precautions, and keep hands OFF hot terminals.

CAUTION - DON'T apply power, until circuit is checked by instructor.

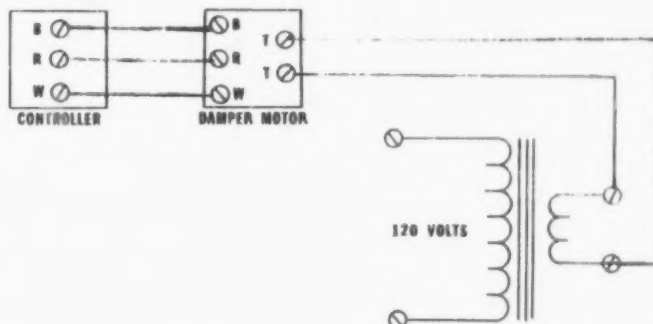


Figure 2. Control Circuit

1. Connect wires as indicated in Figure 2. (have instructor check your wiring before continuing on to the next step.)
2. Apply set point pressure (10 psi) to controller (don't change this pressure)
3. Center signal wiper arm located in controller visually.
4. Center signal wiper arm using ohmmeter (isolate the controller)
5. When the circuit has been checked by instructor, connect a source of power.
6. Decrease the pressure at controller.
7. Viewing the motor from the power end, does the motor shaft rotate clockwise or counter clockwise.

PART 3

OBJECTIVE

Working as a member of a team and using a Refrigeration Controls Trainer, isolate two instructor induced electrical controls malfunctions with two instructor assists.

PROCEDURE

Using service analysis chart, and Refrigeration Controls Trainer, isolate two instructor induced electrical malfunctions. List your observations, trouble, and remedies on the blank chart provided.

CAUTION - Remove all jewelry, observe all safety precautions

	OBSERVATION	TROUBLE SUSPECTED	REMEDY PERFORMED
#1			
#2			

SERVICE ANALYSIS CHART

PART 4

OBJECTIVE

Given a disordered list of steps for replacing electrical controls, place them in a logical order with 70% accuracy.

PROCEDURE

Place listed steps in logical order. Each step will be used only once.

Steps for Replacing an Electrical Control

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____

- a. Check for loose, frayed, or corroded connections.
- b. Check for proper operation.
- c. Apply power.
- d. Remove all jewelry, observe all safety precautions.
- e. Calibrate if necessary.
- f. Remove all power from circuit.
- g. Replace electric control.

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ELECTRONIC CONTROLS

PART 1

OBJECTIVE

Given five basic electronic diagrams, draw lines to indicate current flow through the circuits. Three of the five circuits must be correct.

PROCEDURE

Respond to the following statements/questions by drawing lines and/or arrows to show the current path and direction of current flow. Answer the questions in the space provided.

1. On Figures 3 and 4 below, draw arrows to indicate current flow through the circuits.

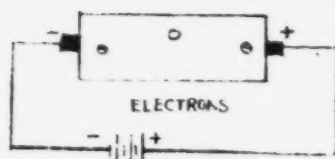


Figure 3

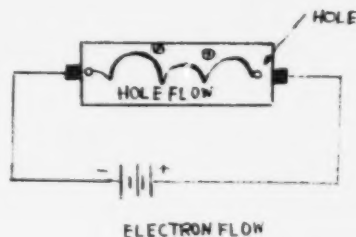


Figure 4

2. Draw lines on Figure 5 to indicate current flow thru circuit. Draw arrows to show direction of current flow.

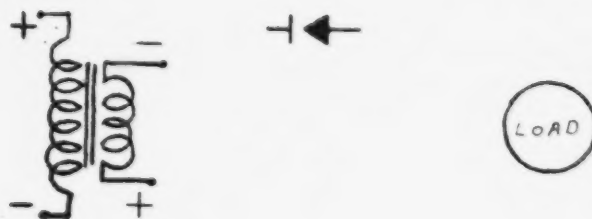


Figure 5

3. Indicate how the devices in Figures 6 and 7 are biased by filling in the blanks below. Draw lines to indicate current flow.

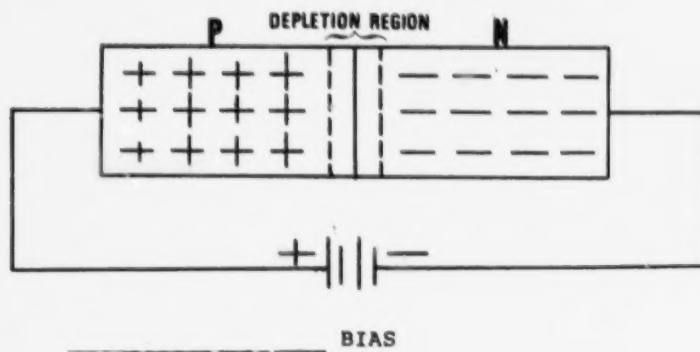


Figure 6

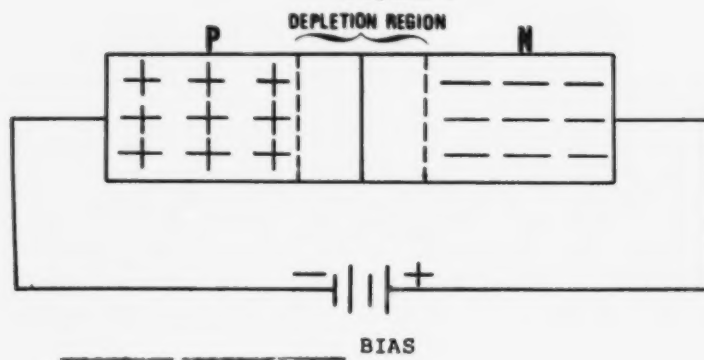


Figure 7

4. Using the Junction Transistor in Figure 8, indicate current flow thru the circuit using arrows.

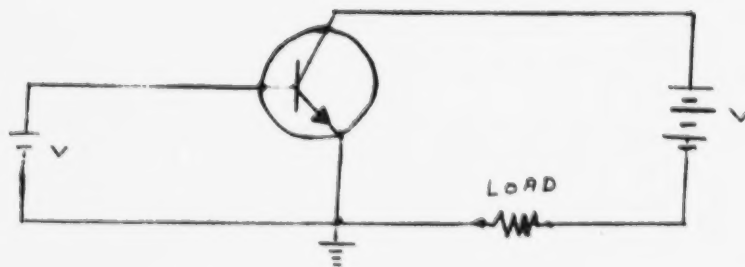


Figure 8

PART 2

OBJECTIVE

Given a schematic of a Bridge Circuit, describe its function and draw lines to indicate flow through the device for one cycle. Two errors permitted.

PROCEDURE

Draw arrows to indicate current flow thru the bridge circuit in Figure 9, also list its function in the space provided.

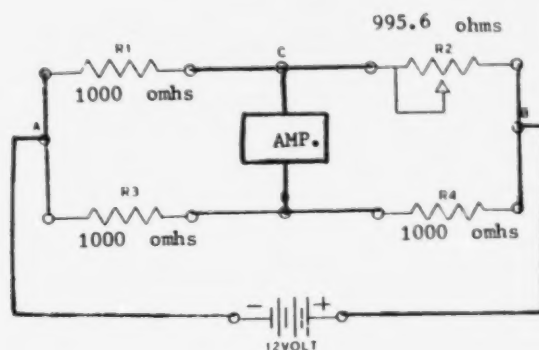


Figure 9

Function - _____

PART 3

OBJECTIVE

Given a list of five electronic components, state their application to electronic controls. Four of the five must be correct.

PROCEDURE

List the application to electronic controls of the five electronic components listed.

APPLICATION

1. Diode - _____

2. PNP Transistor _____

3. NPN Transistor _____

4. Capacitor _____

5. Inductor (choke coil) _____

PART 4

OBJECTIVE

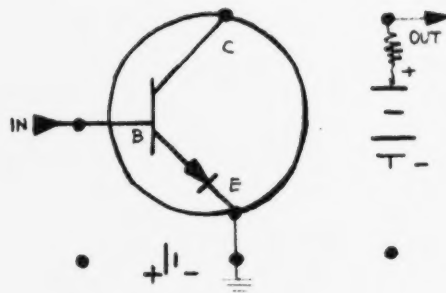
Given the information, trace the flow through a simple amplifier circuit and state its purpose. Two errors permitted.

PROCEDURE

Draw lines to connect the amplifier in Figure 10, then trace current flow thru the simple amplifier circuit and state its purpose in the space provided.

Purpose _____

Figure 10, Simple Amplifier Circuit



PART 5

OBJECTIVE

Given the information, state the purpose, use and operating principles of electronic control circuits with no more than two errors.

PROCEDURE

Using notes and material given, answer the following questions.

1. What is the purpose of an electronic control circuit?

2. What is the use of an electronic control circuit?

3. What is the current flow between two resistors of equal value wired in parallel?

4. This is known as a simple _____ circuit.

5. When the sensing element in the bridge circuit senses a change in variable, the circuit becomes _____.

6. What type sensing element is used to sense the variable of temp?

7. What type sensing element is used to sense the variable of humidity?

8. Will current flow across a balanced electronic bridge circuit? _____ Explain.

9. What do transistors do in a amplifier circuit? _____

10. What do transistors do in a discriminator circuit? _____

PART 6

OBJECTIVE

Given the information, state the operating principle of modulating electronic controls. Only one error permitted.

PROCEDURE

Using notes and material given, answer the following questions.

1. What causes a signal to be sent from the bridge circuit of a modulating electronic control loop? _____

2. Does current flow thru a balanced modulating electronic control loop? _____
Explain. _____

3. Why does a "modulating" electronic control loop provide more accurate control than two-position electronic control loop? _____

4. Transistors when used in a modulating electronic control circuit can be used for _____ and _____.
5. Small changes in the _____ will cause a small change in the position of the _____.

PART 7

OBJECTIVE

Given the information, state the procedure for troubleshooting electronic controls and replacing the controls with no more than two errors.

PROCEDURE

Using notes and material provided, read the following sentences and fill in the blanks provided to complete the sentences.

1. If nothing operates, check the _____ first.
2. Check for _____ with ohmmeter which would indicate infinity.
3. Check for _____ with ohmmeter which would indicate zero resistance.
4. Check for loose, dirty, or corroded connections which would cause a _____ power condition.

PROCEDURE

Using notes and any material provided, list the five steps for replacing an electronic control.

1. _____

_____.
2. _____

_____.
3. _____

_____.
4. _____

_____.
5. _____

_____.

Read the following paragraphs. Fill in the blanks to complete the sentence.

1. Check the balco wire, it must have a resistance of _____ ohms at the 74° F.
2. Check resistance change of balco wire, it must go up _____ ohms for each 1° f. temp change.
3. Check voltage change of balco wire, it must change _____ volts for each 1° f temp. change.
4. Check resistance of goldleaf grid, it must have a resistance of _____ at a dry relative humidity.
5. Check resistance of goldleaf grid, it must have a resistance of _____ at a wet relative humidity.
6. Remove the _____ from circuit before replacing electronic controls.

ADJUSTING CONTROL POINT ON A HONEYWELL MODIFIED BRIDGE

CAUTION - Remove all jewelry, observe all safety precautions

1. Examine the trainer schematic and identify the following:
 - a. Stepdown transformer
 - b. Bridge rectifier
 - c. Modified wheatstone bridge
 - d. Balco wire sensing element (remove thermostat cover)
2. Connect trainer to power source and turn power switch on.
 - a. Determine room temperature.
 - b. Turn thermostat setpoint dial to ambient temperature.
 1. Is current flowing across the bridge? _____
 2. Is the bridge balanced or unbalanced? _____
 - c. Adjust the control point adjuster, located on the side of the trainer, to zero the meter.

Have the instructor check your work.
 - d. Lightly exhale so the thermostat sensing element can sense the heat from your breath.
 - (1) What happened to the current flow across the bridge? _____

 - (2) What must happen for the bridge circuit to become unbalanced?

 - e. Blow at the thermostat so the sensing element can sense the cool air.
 - (1) What happened to the current flow across the bridge? _____

 - (2) If this bridge circuit were part of a phase detector circuit, what component would take the place of the ammeter?

Have your instructor check your work.
 - f. Disconnect the trainer from the power source.

Technical Training

Refrigeration and Cryogenics Specialist

COMMERCIAL AIR CONDITIONING

November 1982



3700 TECHNICAL TRAINING WING
(3770 Technical Training Group)
Sheppard Air Force Base, Texas

FOR ATC COURSE USE ONLY

DO NOT USE ON THE JOB

AIR HANDLERS

OBJECTIVE

Upon completing this unit of instruction, you will be familiar with:

- The steps required to replace air handler bearings, shafts, belts and pulleys; and adjustment of damper linkage.
- The steps for lubricating air handler bearings and checking the bearings, belts and pulley alignment.

INTRODUCTION

Air conditioning can be defined as control of temperature, humidity, filtration and circulation of air. To condition the supply air is a function of air handlers. The arrangement of filters, dampers, pre-heat, reheat, chill water coils, air wash or steam grid and dampers within the air handler make this possible. The larger systems are used with indirect expansion systems, which normally use a centrifugal or absorption chiller to supply the chill water.

Assignment in Preparation for Day 46

I. AIR HANDLERS, CONSTRUCTION FEATURES

A. Read the following paragraphs and answer the questions.

Indirect expansion systems will use two types of air handlers, but only one or the other, not both as we have here.

First there is the multi-zone air handler which is a system with four separate supply air ducts. The conditioned air leaving these ducts is heated or cooled depending on what the controller for that certain zone is calling for. All four ducts could carry four different supply air temperatures to different areas of a building. The temperature is controlled by a set of dampers for each zone which modulate air flow across the heating or cooling coil and then mixing it for proper temperature.

The second air handler is called a single zone type. This type system has only one supply air duct with one supply air temperature. The temperature of the air being produced by the air handler is controlled by modulating water valves located on the cooling and heating coils. As the temperature goes up, the chilled water valve will open more and the hot water valve will close. These two valves are operated by a series-90 control loop, with the sensing element located on the return air side of the system.



Multi-Zone Air Handler

B. Read the following paragraphs and answer the questions.

Both the multi-zone and single-zone air handlers have damper assemblies which allow the system to exhaust all return air and take in all outside air, or mix return with outside while still exhausting a portion of the return air. All large buildings being conditioned should exhaust air. The reason for this is to get rid of unwanted impurities, such as smoke and odors.

The motors for the air handlers are located outside the unit which allows the airflow patterns through the unit from being disrupted. Static pressure loss and thus horsepower are held to a minimum. Proper coil loading is also maintained. Motor and bearing noises, including 60-cycle hum, are not carried into the duct system. At the exterior location the motor is not subjected to extreme air conditions that exist inside the unit. Also, the motors are easily accessible and can be inspected regularly and given proper maintenance.

1. What is the purpose of damper assemblies?

2. What is the purpose of exhausting air?

3. Where is the motor for the air handler located?

C. Read the following paragraphs and answer the questions.

Now that you have a basic understanding of air handlers and the function of the various components, we will learn some elementary replacement, repair and adjustments to maintain the efficiency of air handlers.

Fans

Fans are essential for circulation of air. Ventilation is the means of providing oxygen for people and removal of heat and airborne pollutants.

Air movement becomes a critical factor when analysis of maintenance or adjustment of air handling systems are considered.

Some items to consider when performing maintenance: Worn bearings, broken or slipping belts, proper lubrication, bent fan blades, dirt on fan blades or unbalanced fans.

Belt pulley alignment, tension of belts, flats on pulley or burned spots on belts. If there is more than one belt, all belts should be replaced as a set. Not just one at a time.

Dirt and grease when exposed to excess heat can catch fire within the enclosed space.

Belts can be adjusted by usually moving the motor, or in some instances adjustment of variable pitch pulley.

From the preceding statement you can understand the importance of the fan and its function of air movement.

1. What is the purpose of the fans?

2. When does air movement become a critical factor?

3. How may the V-belts be adjusted?

D. Read the following paragraphs and answer the questions.

Filters

Filters are important in that they are essential in removal of dirt or solid particles. Other types of filters remove odors, gases or bacteria.

They come in two classes: permanent or throw-away.

Filters, as they become saturated with precipitants, begin to restrict air flow, this extent of static restriction can be measured on draft gages and manometers. Usually expressed in MM or inches of water, .05" to .24" is a range sometimes used to indicate faulty filters.

Normal procedures is to clean or replace filters depending on the class of filter.

1. What are the two classes of filters?

2. What is the purpose of the filters?

E. Read the following paragraphs and answer the questions.

Dampers

Dampers are the final control device for regulating the quantity of air, its mixture, or direction of flow. Dampers are used to balance the air flow to the various rooms, as mixing air (return, outside, or two different temperatures) for control of humidity, temperature or ventilation.

There are three basic types: (1) Butterfly (2) Multiple blade (3) Split damper

They can be operated either manual or automatic.

They must be properly fitted and sized for ducts and control of airflow--free from dragging, jamming or working out of shape in normal usage. Corrosion and accumulation of excess dirt can be a problem in some applications.

DAMPER MAINTENANCE. Most damper rods revolve in nylon bushings which do not require lubrication. Check linkage, setscrews and blade adjustment periodically for proper operation or adjustment.

Controlling devices should be checked periodically to insure that the dampers are operating from full-open to full-closed position.

1. What is the purpose of the dampers?

2. What are the three types of dampers?

3. How many dampers be operated?

II. AIR HANDLERS, MAINTENANCE

A. Read the following paragraphs and answer the questions.

Periodic Maintenance Air Handlers

a. Monthly--

- (1) Inspect the air filters and, if necessary, clean or replace.
- (2) Check spray coil sump, water drain, and check for scale and corrosion. Adjust float makeup valve.

b. Every three to six months--

- (1) Bearing should be lubricated, if possible, with motor running. Add grease until a slight bead appears. Check bearing races for excess wear.
- (2) Adjust belt tension on fans--approximately 1/2 inch flex in each direction. When replacing belts replace with complete set.
- (3) Motor lubricants should be checked every three to six months. Depending on operating time. Remove bottom plug--install grease fitting at the upper plug and lubricate until approximately 1/2 inch of old grease is forced out--run to expel excess grease, replace plugs.

CAUTION: Do not use oils containing detergents!

- (4) Inspect the unit coils for dirt or damage. Use "fin comb" to straighten fins. Air jet to clean dirt.

CAUTION: Do not use steam or hot water to clean
refrigerant coils when charged!

- (5) Spray humidifiers for lime deposits. If lime deposits have developed, clean by soaking nozzles in an oxalic acid solution and then clean thoroughly by soaking in water. Inspect the muslin wrap sleeve on the steam grid humidifier and replace if necessary.

1. What is the proper belt tension?

2. What is required to straighten the fins on the coils?

B. Read the following paragraphs and answer the questions.

c. Once a year--

- (1) Inspect the unit casing and accessories for paint chipping and corrosion. Clean and repaint as needed.
- (2) Clean fan on fan shaft. If rusted, remove rust and recoat with rust preventive.
- (3) Inspect drain pan for sludge and clean as needed.
- (4) Check condensate drain line to insure it is not blocked.
- (5) Check damper linkage, setscrews, and blade adjustment for proper operation.

NOTE: It is not necessary to lubricate.

- (6) Grease fan bearings.

Steps:

- (a) Remove bottom plug--clean out old grease.
 - (b) Add fresh grease through upper grease plug using low pressure gun.
 - (c) Run the motor for a few minutes to expel any excess grease out through the removed bottom plug.
 - (d) Replace bottom plug.
 - (e) Wipe off any excess grease.
- (7) V-belt drive.
- (a) All v-belt drives should be checked periodically for alignment, proper belt tension, belt wear and cleanliness.
 - (b) Check motor and fan shafts for parallel alignment--use a level. Adjust motor sheaves for parallel alignments. The use of belt dressing is not recommended for v-belts.
 - (c) Belts should be tight enough to avoid squeal and slippage during operation. A slight squeal during start up is normal. Excessive belt tension will increase fan and motor bearing wear as well as shorten belt life.

1. List the steps for greasing fan bearings.
2. List the steps for aligning pulleys and replacing fan belts.
3. List the major components of an air handler and define their function.
4. How does the air handler affect the overall function within an air conditioning system?

CENTRIFUGAL AIR CONDITIONING

OBJECTIVE

Upon completing this unit of instruction, you will be familiar with:

- Principles of operation of a centrifugal air conditioning system.
- The refrigerant, chilled water, and condenser water circuit.
- The steps required for charging a centrifugal system with refrigerant.
- The maintenance procedure on a centrifugal air conditioning system.
- The purge unit operation.

INTRODUCTION

The centrifugal compressor is a low-pressure machine using impellers for compression purposes. The refrigeration cycle is accomplished with refrigerants having a compression range of not over 30 psi. The centrifugal machine can be either motor or turbine driven and usually runs at high speeds, 3600 to 6900 RPM. They vary in capacity from less than 100 to approximately 3000 tons of refrigeration per unit. Since centrifugal units have a greater cooling capacity, they are used in larger air conditioning installations.

Centrifugal equipment uses the indirect method of cooling. The equipment cools a fluid (usually water or brine solution) that is pumped through a cooling coil in the area to be cooled. The fluid (often called a secondary refrigerant) picks up the unwanted heat in the conditioned space and brings it back to the refrigerating equipment where it is removed and discarded.

Assignment in Preparation for Day 46

I. CENTRIFUGAL SYSTEM, REFRIGERANT, CHILLED WATER, CONDENSER WATER CIRCUIT

A. Read the following paragraphs and answer the questions.

The centrifugal system (figure 1) is a compact assembly made up of a condenser, economizer, refrigerant flow control, evaporator, compressor purge unit and control panel, shown in figure 1.

Condenser

The condenser is of standard design shell and tube construction. Condensers on centrifugal machines serve two functions. The primary, as in all condensers, is to receive the hot discharge gas from the second stage of compression and condense it to a liquid. Its secondary function is to trap and hold noncondensables.

Located inside the condenser shell is a special header chamber and baffle. The pressurized refrigerant vapor from the second stage of compression enters to the top of the condenser. This pressurized vapor is distributed throughout the full length of the tube bundle as well as in a downward direction within the condenser shell. The header is perforated permitting the gas to be broken up into irregular patterns into the tube bundle area. This provides a combined blowing and wiping effect, which prevents the formation of an insulating film that would retard the heat transfer.

Condensing water is piped so that the cooler entering water is directed first through the lower tubes of the bundle to be returned through the upper tubes after making only two passes. The net result is a more constant temperature difference between the downward flowing vapor and the tube surfaces. This achieves a more uniform heat transfer across the tube bundle.

Water boxes or end plates are removable on both ends of the condenser. These end plates can be removed without disturbing the refrigerant charge since the tubes themselves are soldered into the condenser flanges. End plates are interchangeable from end to end to facilitate different installations. The inlet flange has a division plate to provide the required two passes. See figures 1 and 2.

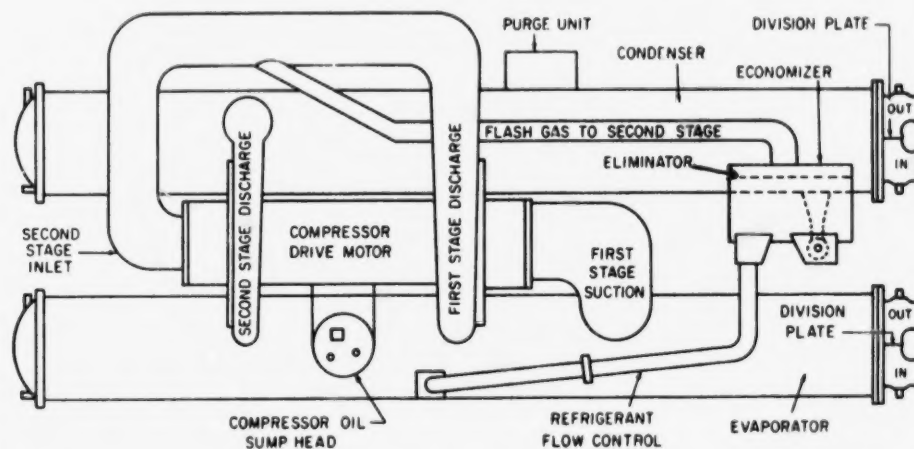


Figure 1. Centrifugal Compressor System

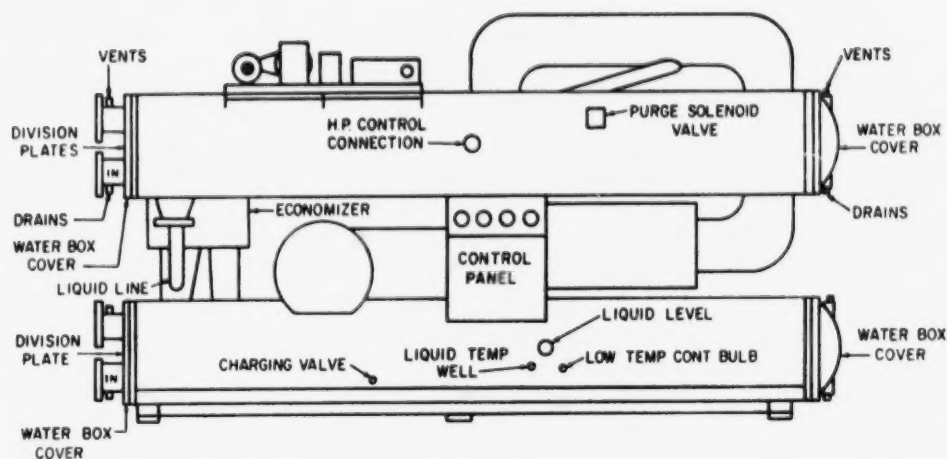


Figure 2. Centrifugal Compressor System

1. What are the two functions of the condenser?

2. What is the purpose of the baffle in the condenser?

3. Where does the discharge vapors and, condensing water enter the condenser? Why?

B. Read the following paragraphs and answer the questions.

Economizer

Once condensed, the refrigerant leaves the condenser through the liquid line and enters the economizer (figure 3). The economizer is an intermediate pressure chamber vented to the second stage suction side of the compressor. The second stage suction pressure is lower than the condensing pressure; therefore, a portion of the liquid will flash. This flashing of liquid cools the remaining refrigerant in the economizer to the temperature corresponding to the second stage suction pressure.

Resulting flash gas passes through an eliminator (figure 3) to remove any trapped liquid refrigerant. It then passes through the vent pipe connecting the economizer to the second stage inlet. This cool gas helps to increase the efficiency of the compressor by cooling the discharge gas coming from the first stage. The remaining liquid in the economizer, now at inter-stage pressure and temperature, continues through the liquid line to the refrigerant metering system at the evaporator.

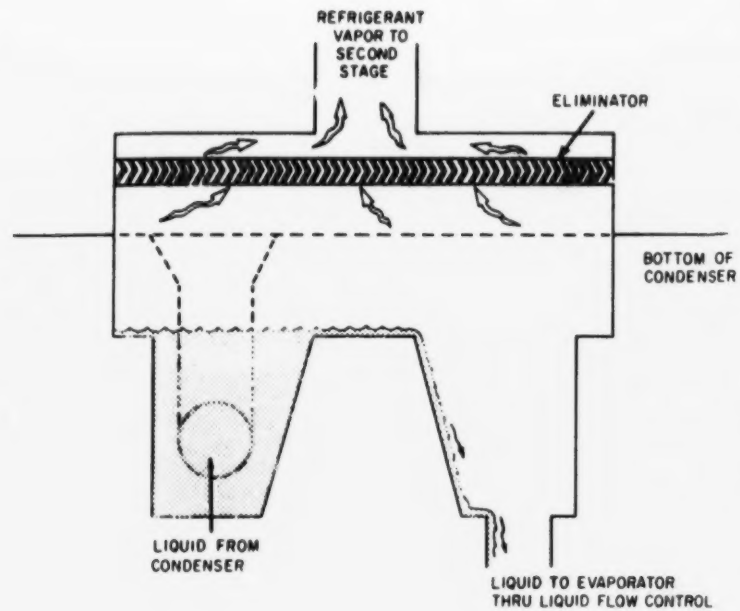


Figure 3. Economizer

1. What is the function of the economizer?

2. What is the function of the eliminators in the economizer?

3. Where does the flash gas from the economizer enter the compressor?

C. Read the following paragraphs and answer the questions.

Refrigerant Flow Control

Liquid refrigerant leaving the economizer is metered to the evaporator by a very unique refrigerant flow control (figure 4). It has no moving parts. The purpose of this metering system is to maintain the design refrigerant flow required for each load condition. No matter if the load is high or low.

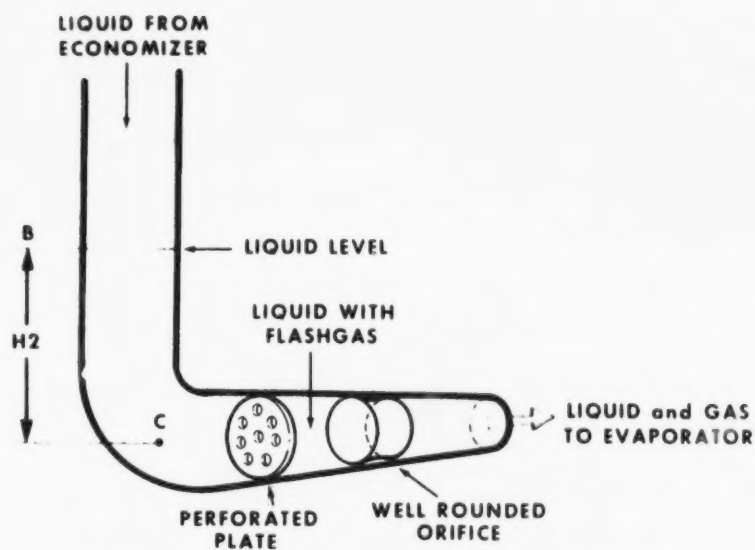
As the liquid passes from "C" (figure 4) through the orifice system, it is subject to successive pressure drops. The first component of the system is a perforated plate which is designed to meter liquid refrigerant only. The next component is a well-rounded orifice which is designed to meter either liquid or a liquid gas mixture. The well-rounded orifice is a choke which meters almost a constant volume flow of liquid or liquid gas mixture, regardless of the pressure difference.

For example, at rated full flow (full load), the constant volume metering characteristics of the orifice system limits the flow of liquid until the level rises to point "A" (figure 4) in the liquid line. Liquid at point "A" is at saturated liquid pressure (condenser pressure) while the pressure at "C" (figure 4) is at a higher pressure because of the liquid head H-1. This liquid head is created by the perforated baffle. By pressurizing the liquid in this manner, it produces a subcooling effect on the refrigerant which prevents any flashing of liquid unless the pressure drop across the perforated plate is equal to or greater than the pressure of head H-1.

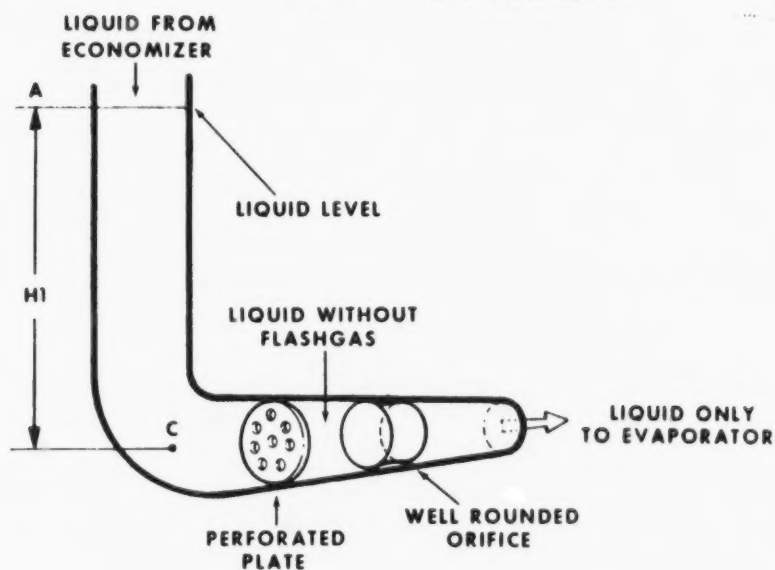
At full load conditions, the pressure drop across the perforated plate is less than head H-1, which means that subcooled liquid is passed to the well-rounded orifice without flashing. At this point, the orifice is metering the maximum volume of liquid to the evaporator.

As the load on the system decreases, the mass flow of refrigerant decreases, causing the level or liquid head in the liquid line to drop. Subcooled liquid refrigerant continues to flow through the well-rounded orifice until the pressure drop across the perforated plate equals the pressure of the liquid head H-2 in the liquid line. Figure 4 shows this taking place when the level falls to "B." At this point, liquid passing through the plate is reduced to the saturated liquid pressure (condenser pressure) causing it to flash. Once flashing starts, a mixture continues to pass a constant volume flow. However, the nature of the flow has changed. It now contains flash gas which displaces the liquid resulting in a reduction in the net volume flow of liquid.

A further drop in load causes another drop in the liquid head in the liquid line. This will cause more liquid refrigerant to flash as it passes through the perforated plate, again reducing the volume flow of liquid through the well-rounded orifice to the evaporator.



a. SYSTEM UNDER LOW LOAD



b. SYSTEM UNDER HIGH LOAD

Figure 4. Refrigerant Metering System

1. What is the purpose of the refrigerant flow control?

2. What is the function of the well-rounded orifice?

3. Describe the operating principles of the refrigerant flow control?

D. Read the following paragraphs and answer the questions.

Evaporator

The evaporator located at the bottom of the unit is of standard design shell and tube construction. Similar to the condenser, it is a flooded-type evaporator, which means the water tubes within its shell are immersed in liquid refrigerant. The normal refrigerant charge in the evaporator covers only about 50 percent of the tube bundle as indicated by the liquid level sight glass. However, during operation, the violent boiling of the refrigerant usually covers the tube bundle.

A rupture valve with a 10-pound bursting disc is provided on the evaporator to prevent possible damage to equipment.

Uniform heat transfer throughout the evaporator (figure 5) is promoted by a liquid distributor which runs the length of the shell. Liquid refrigerant, or a liquid gas mixture, is metered into the distributor through the orifice system previously described. The pressure drop across the final component of the orifice system, the well-rounded orifice is high. Therefore, the liquid flashes as it passes into the distributor. This sensibly cools the remaining liquid to evaporator temperature.

Since flash gas occupies approximately 150 times the volume of an equal weight of liquid, the presence of flash gas in the confined area of the distributor produces a pressure drop across the distributor orifices (figure 5). Because of the pressure drop, the liquid-gas mixture enters the evaporator as a high velocity jet. To prevent erosion of the tubes, resulting from direct impact of the liquid gas on the tube bundle, the distributor orifices direct the jets against baffles which tends to soften the jet spray in a vertical direction. The spray creates turbulence within the tube bundle which promotes uniform wetting of the water chilling surfaces.

A large volume collection chamber directly above the heat transfer area (figure 5) moderates the velocity of the leaving vapor. This prevents liquid refrigerant from being carried upward through the eliminator and back to the compressor.

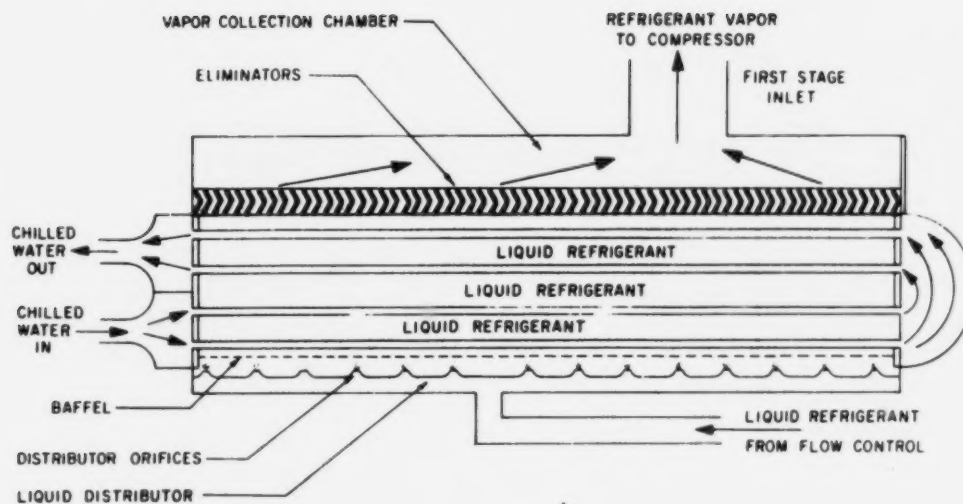


Figure 5. Evaporator

1. Why does the evaporator have a liquid distributor and orifices?

2. What is the function of the eliminators in the evaporator?

3. What is the function of the collection chamber in the evaporator?

E. Read the following paragraphs and answer the questions.

Centrifugal Compressor (Hermetic Type)

The easiest way to understand the functions of a centrifugal compressor is to think of it as a centrifugal fan of the type used for forced and induced air flow. Like the fan, the compressor takes in gas at the center and whirls it at a high speed, which compresses the gas by centrifugal force. The high velocity of the gas leaving the impellers is converted to a pressure exceeding the inlet pressure.

The compressor has two stages of compression. The impellers are arranged back to back on the motor shaft, with the thrust of one impeller balancing the thrust of the opposing impeller. The impellers are fully shrouded or encased. Both back and face of each impeller are enclosed. The fully shrouded impellers permit ample clearance between impellers and volute, materially increasing reliability. The integral motor-impeller assembly operating at 3600 RPM is the only major moving part. Both twin impellers are keyed to the motor shaft to form a single rotating assembly. The shaft itself runs on two journal bearings.

Capacity of the compressor is regulated, to balance the refrigerant flow with evaporator load, by pneumatically actuated inlet guide vanes. These vanes are located immediately ahead of each stage of compression on the inlet side. Using figure 6 as a guide, refrigerant gas enters the first stage inlet (A), passes through the inlet guide vanes (B). These vanes not only regulate flow but they also pre-rotate the gas causing it to enter the impeller (C) at the optimum angle. The impeller accelerates the gas and discharges it through a circular diffuser passage (D) into the volute. Here the kinetic energy (energy of motion) imparted or given to the gas by the rotating impellers is converted to static pressure. Discharge gas from the first stage then enters the crossover pipe. Before entering the second stage, it is cooled by flash gas coming from the economizer. The cooled discharge gas now enters the second stage inlet (E) and second stage inlet guide vanes (F), where it is compressed again. After this second compression, the gas is discharged into the condenser.

Each impeller is subjected to forces exerted on its surface by the pressurized gas. The net effect of these forces results in thrust. The back to back impeller arrangement causes the thrust of one impeller to oppose the thrust of the other. The result of these two opposing forces is a balanced thrust condition. With balanced thrust, only simple sleeve bearings with thrust collars are required to support and position the impeller motor shaft.

The compressor motor is cooled by the chilled water produced by the system. The water is circulated through a motor jacket by the same pump which supplies chilled water to the air conditioning system. The whole system is very similar to the cooling system on a car.

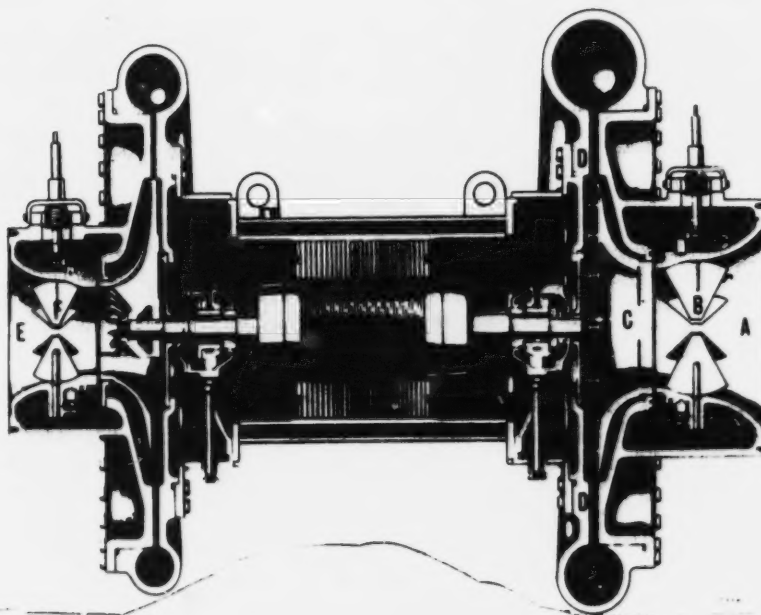


Figure 6. Centrifugal Compressor

1. How is the capacity of the compressor regulated?

2. How is the compressor motor cooled?

STOP!

You have completed the assignment in preparation for Day 46.

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Assignment in Preparation for Day 47.

II. PROCEDURES FOR CHARGING A CENTRIFUGAL SYSTEM

A. Read the following paragraphs and answer the questions.

Checking Refrigerant Level

To obtain an accurate indication of refrigerant charge level, the refrigerant in the economizer must be returned to the evaporator. The necessary piping arrangements for this process is illustrated in figure 7.

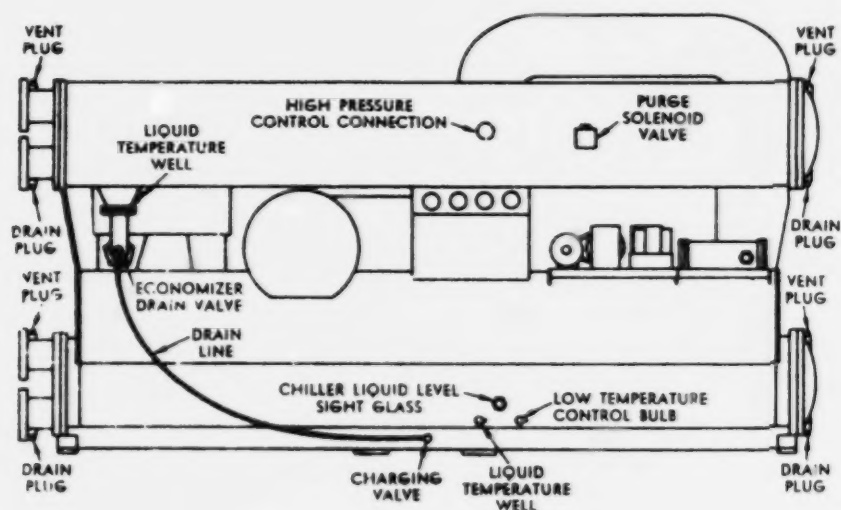


Figure 7. Checking Refrigerant Level

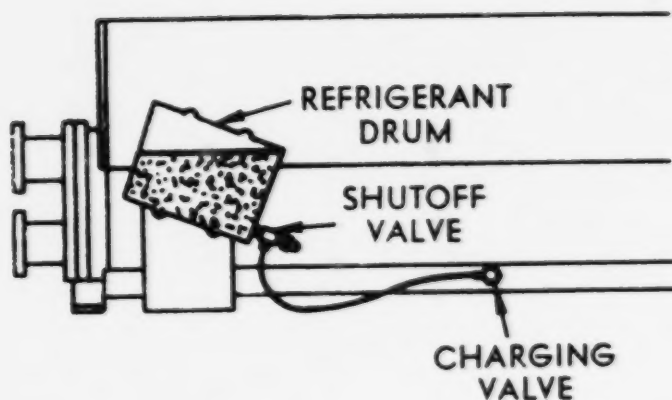


Figure 7. Charging, Liquid

Using either vacuum hose or copper tubing, connect the lines to the valves, as indicated. When valves are opened, refrigerant will flow by gravity to the evaporator.

When properly charged, the liquid level will appear at the center of the evaporator sight glass. This will be equal to approximately 300 pounds of R-113.

Adding Refrigerant

Accurately check refrigerant level before attempting to add refrigerant. If refrigerant level is low, determine the cause for the loss before proceeding.

- ☐ Pipe a drum of R-113 to charging valve as shown in figure 8.
- ☐ Elevate drum above liquid level in evaporator to induce a gravity flow.
- ☐ Charge until liquid level appears in center of evaporator sight glass.
- ☐ Close charging valve and disconnect refrigerant drum.

1. What is required to obtain an accurate indication of a refrigerant charge level?

2. How does the refrigerant flow from the economizer or from the refrigerant drum?

3. How is the correct charge indicated?

B. Read the following paragraphs and answer the questions.

Leak Testing

To leak test the unit effectively, a positive pressure must be developed within the system. The test pressure is developed with oil pumped dry nitrogen. Refrigerant vapor within the unit serves as a tracer gas for leak detection.

WARNING: DO NOT use oxygen or acetylene in place of nitrogen for leak testing. A violent explosion may result. Always install a pressure regulating valve in pressure hookup to prevent unit from being subjected to excessive pressure.

- ☐ Close evaporator gauge connection valve and remove gauge connection.
- ☐ Connect a drum of oil pumped dry nitrogen to valve fitting.
- ☐ Charge enough nitrogen into the unit to develop a 10 psi test pressure.

WARNING: Under no circumstances exceed the 10 psig test pressure specified. Pressure in excess of 10 psig will cause evaporator relief disc to rupture.

- ___ Close evaporator gauge connection and remove nitrogen charging equipment.
- ___ Proceed with normal leak checking procedures, using either a Halide or electronic leak detector.

1. What is used to pressurize a centrifugal system?

2. To what pressure is the system pressurized for leak checking?

- ___ Connect a line to the oil charging valve. Figure 8.

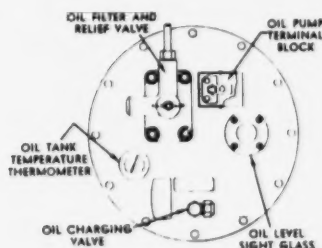


Figure 9. Compressor Oil Sump Cover

- ___ Insert end of line into a container.
- ___ Open valve and leave open until oil flow stops. Close valve.

Filling:

- ___ Loosely connect the discharge side of an auxiliary oil pump to the oil charging valve.
- ___ With the charging valve closed, operate pump until oil appears at loosened connection. Tighten connection.
- ___ Open valve and pump oil into the sump until the required oil charge has entered the sump.
- ___ Remove filler line and close valve.
- ___ Energize oil sump heater.
- ___ Purge system to remove nitrogen.

Adding Oil

Before adding oil, determine the cause for the loss.

- ___ Check condition of oil sump heater and oil temperature control setting.
- ___ To add oil, follow the steps for Filling Oil Sump, as outlined in compressor oil change.

C. Read the following paragraphs and answer the questions.

Changing Compressor Oil

The design oil charge for the compressor is seven gallons. Approved oils are Texaco Capella "D" and Mobil Whiterex No. 425.

If compressor oil is to be changed at the time the system is to be leak-tested, pressurize system to a slightly positive pressure and then drain oil from sump.

Pump new oil into sump before developing the full pressure necessary for leak test.

WARNING: De-energize oil sump heater by opening control panel disconnect switch before draining the sump. Otherwise, heater may burn out.

Draining Oil Sump:

___ Pressurize system to a 1 to 2 psig positive pressure. Figure 9.

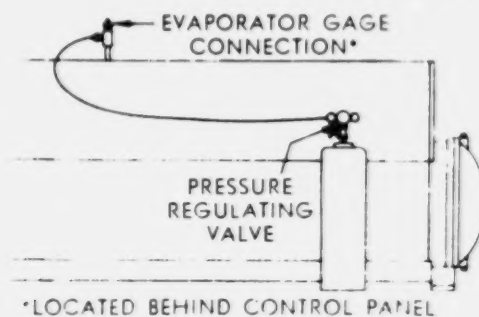


Figure 8. System Pressurizing

1. What are two types of oil that is approved for centrifugal compressors?

2. Why is the oil sump heater de-energized before draining the sump?

3. To what pressure is the system pressurized for draining the oil sump?

III. MAINTENANCE OF A CENTRIFUGAL SYSTEM

A. Read the following paragraphs and answer the questions

Secondary Refrigerant and Condenser Water Systems Maintenance

It is very difficult to set up a definite maintenance schedule since so many operational factors must be considered. Your supervisor should familiarize you with the standing operating procedures at your installation and you must follow these recommendations.

The tubes in the condenser and cooler must receive regular attention for efficient performance and long life. Special care must be taken during the first year of operation due to dirt and other foreign materials which may have collected in the system during installation. The water treating system must operate effectively to prevent general corrosion of the tubes and piping system. Foreign material and corrosive attack can do extensive damage to the system's piping and water tubes if not effectively treated and corrected.

The trainer has an expansion tank for the chilled water and one for the heat transfer unit or hot water. A coil and shell assembly is used for the heat exchanger.

A cooling tower and a storage tank is provided for the condenser. The water is circulated through the system and into the tank. If the temperature of the water reaches a certain degree, a butterfly valve will route the water to the cooling tower and back to the tank. This type of system is commonly called a dry sump cooling tower.

Flow switches are installed in the chilled water lines and the condenser water lines.

1. What is the possible effect if the system's piping and water tubes are not effectively treated and corrected?

2. What is dry sump cooling tower?

B. Read the following paragraphs and answer the questions.

CLEANING THE CONDENSER: Water available for condensing frequently contains minerals that collect on the condenser tube walls as carbonate scale. Scale accumulation rate will be increased by high condensing temperatures and water with a high mineral content.

Cooling tower may collect dust and foreign material that will deposit in the condenser tubes forming sludge. Scale and sludge formation is indicated by decreased water flow, high condensing temperatures and large differences between condensing and leaving water temperatures.

To maintain maximum efficiency, the condenser must remain free of scale and sludge. Even a very thin coating on the tube surface may greatly decrease condenser heat transfer capacity.

The two methods for cleaning condenser tubes are mechanical and chemical.

The mechanical method removes sludge and loose material from condenser tubes. Working a round nylon or bristle brush, attached to a rod, in and out of the tubes loosens the sludge. After cleaning, flush the tubes with clear water.

The chemical method removes scale deposits. The standard condenser water circuit consists of copper, steel and cast iron. Any reliable chemical house in the area, knowing the chemistry of water, will be able to recommend a cleaning solution for the job.

A chemical feeder has been installed on the chilled water system to aid in scale removal, while the condenser water system doesn't, due to it being an open system.

1. What are the two methods for cleaning the condenser tubes?

2. How is the sludge and loose material removed from condenser tubes?

C. Read the following paragraphs and answer the questions.

Centrifugal Compressor Lubrication System

The two compressor bearings which support the main impeller shaft are lubricated by a forced-feed system. Pressurized oil is fed to the bearings by a motor driven oil pump which is submerged in the oil sump, figure 10. Bearing oil pressure is controlled by a regulating valve located in the pump discharge line. The regulating valve is adjusted to maintain a constant 12 psi usable oil pressure. Usable oil is determined by subtracting evaporator pressure from indicated oil pressure as shown on the gauge. The bearing oil pressure is monitored by an oil pressure control. The purpose of the control is to assure proper oil pressure to the compressor bearings at all times during operation. It measures the net or effective oil pressure at the bearings and is interlocked into the overall compressor control circuit. It will not permit the compressor motor to start until the required oil pressure is built up at the bearings. This is very important since practically all bearing wear occurs at the time rotation begins. In the event of an oil pump failure or a drop below minimum pressure (4 psi), the control will stop the compressor automatically. On a low oil pressure shutdown the oil pump will continue to operate, supplying oil pressure to the bearings.

Oil temperature within the sump is maintained at approximately 130°F by an oil temperature control. This control operates an electrical resistance heater clamped to the exterior of the sump. Refrigerant 113 (Trichlorotrifluoroethane) has a boiling point of 118° at atmospheric pressure. To prevent the system's refrigerant from condensing in the sump and diluting the oil, it must be maintained above its boiling point; this is why the 130°F temperature is required. Oil leaving the sump is cooled to design bearing temperature by an external oil cooler, figure 10. A temperature operated water regulating valve meters the flow of water through the cooler, maintaining the oil temperature at the desired temperature of 110°.

The lubricating oil is gravity returned to the sump after use. For this to happen, pressure must be equalized within the lubricating system to induce the gravity return. This is accomplished by vent lines (figure 11).

- A — OIL PUMP ASSEMBLY
- B — OIL FILTER
- C — RELIEF VALVE
- D — EXTERNAL OIL COOLER
- E — OIL SUPPLY LINES
- F — JOURNAL BEARINGS
- G — OIL RETURN LINES
- H — EXTERNAL OIL HEATER
- I — WATER REGULATING VALVE
- J — OIL TEMPERATURE CONTROL BULB

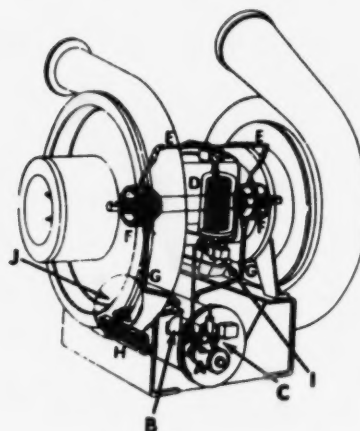


Figure 10. Centrifugal Compressor Lubrication System

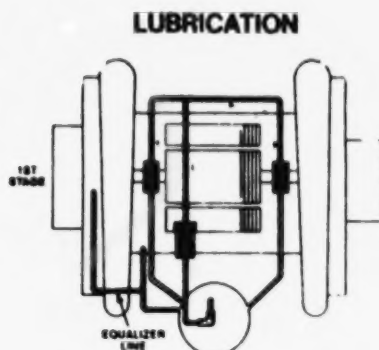


Figure 11. Centrifugal Compressor Lubrication System

1. What temperature is the oil maintained within the sump?

IV. PURGE UNIT OPERATION

Read the following paragraphs and answer the questions.

Purge Unit

The function of the purge unit (figure 12) is to remove noncondensables (air) and water vapor from the refrigerant system.

With practically the entire machine operating under a vacuum, air and moisture may enter the system. If allowed to accumulate, these noncondensable gases will increase condenser pressure. This will result in increased power consumption, decrease the cooling capacity and possible compressor surge.

A mixture of refrigerant gas and noncondensables is drawn from the top of the condenser and compressed by the purge unit compressor. The compressed gas passes into the oil separation tank, where the gas is heated by electrical resistance heaters attached to the side. This prevents refrigerant from condensing and mixing with the oil from the compressor.

Oil that is separated from the refrigerant will collect in the bottom of the tank and will be returned to the compressor crankcase through a float valve and oil return line.

Refrigerant and water vapors leaving the separator enters the purge drum. Located inside the drum is a tube and fin coil with either chilled water from the system, or city water passing through it. This water coil being at a lower temperature than the refrigerant vapor will act as a condenser and liquify the refrigerant and water. Air being lighter than both refrigerant and water will separate and rise to the top of the drum. When the pressure within the drum exceeds the automatic relief valve setting because of excessive air in the drum, the valve will open, releasing the noncondensables to the atmosphere. The liquid refrigerant laying in the bottom passes through the float valve and reenters the system through the evaporator side.

Water being heavier than air but lighter than the refrigerant, will float on top of the liquid refrigerant in the bottom. Any accumulated water floating on the refrigerant will be indicated by a raising level in the sight glass. This water is removed manually by opening the blow-off valve located on the end of the purge drum.

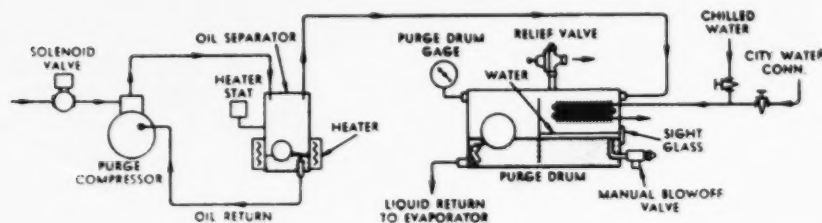


Figure 12. Purge Unit

1. What is the function of the purge unit?

2. Why does the purge oil separator require a heater?

3. The component of the purge unit that separates water from the refrigerant is the

V. OPERATION OF A CENTRIFUGAL SYSTEM

- A. Read the following paragraphs and answer the questions.

Compressor Capacity Control

A sensor-transmitter, receiver-controller type of pneumatic control system is used to throttle the suction vanes on both first and second stage inlet for capacity control (figure 13). In operation, a rising supply chilled water temperature causes the direct acting sensor-transmitter to increase its pressure to the input port II on the controller. In turn, the receiver-controller proportionally increases the pressure at "O" supplying more pressure to the pilot chamber of the pilot positioner located on the vane operator. At the same time pressure is applied to the pneumatic electric switch PE 1 (figure 13a). When the output pressure from the controller reaches the setting of PE 1 (close 5 psi, open 1 psi), the contacts close starting the centrifugal compressor.

Energizing the compressor starting circuit also energizes the solenoid air valve SAV after a short time delay, placing the receiver-controller in control of the compressor vane operator. From this point on, the chilled water temperature control system modulates the compressor inlet vane position, balancing compressor capacity with the system load.

The unit also has a load limiting mechanism (figure 13b). This mechanism is located in the unit's control panel and is piped into the pneumatic system between the pilot positioner and the vane operator. The load limiting system consists of an electric-pneumatic relay and an electrically operated three-way air valve. The only time the three-way valve allows air to pass to the vane operator is when the compressor is energized. This in effect allows the compressor to start in an unloaded condition. When the compressor is shut down, the three-way valve is de-energized, cutting off control air from the pilot positioner and exhausting the air from the inlet vane operator, closing the vanes. Keep in mind that there is only one vane operator that operates two inlet vanes, one on the first stage inlet and the other on the second stage inlet.

1. What control modulates the compressor inlet vane position, balancing compressor capacity with the system load?

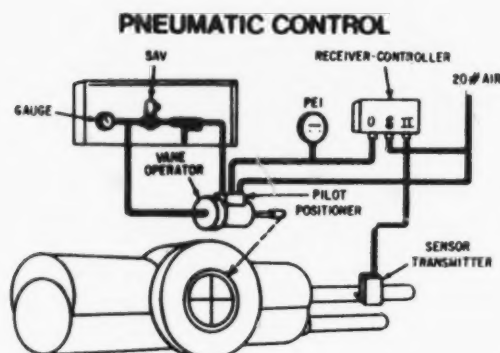


Figure 13a. Pneumatic Compressor Capacity Control

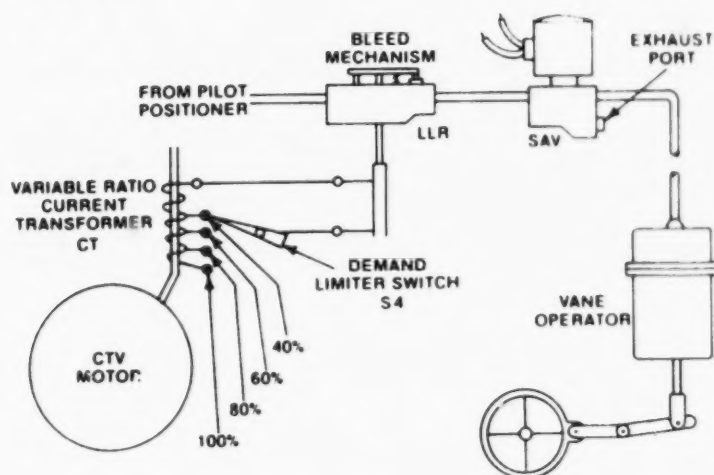


Figure 13b. Compressor Capacity Control

B. Read the following paragraphs and answer the questions.

The second item in the load limiting mechanism is the electro-pneumatic load limit relay. The electromagnetic coil is connected to a current transformer which is installed on one leg of the line side of power going to the compressor motor. The electro-pneumatic load limit relay allows air pressure to be transmitted directly to the inlet vane operator when the compressor motor current is less than 98 percent of its full load rating. However, should the motor current exceed 98 percent, the magnetic pull of the coil becomes great enough to start opening the bleed port of the relay. This bleeds control air pressure from the vane operator causing both inlet vanes to modulate toward the closed position. In this manner, the gas flow to the compressor impellers is throttled, reducing the load on the motor. A reduction in load will also reduce the motor current until it is stabilized at, or below, its 100 percent of full load.

The load limiting relay remains in control, limiting the load on the motor, until the motor's load drops below the control range of the relay. At this point, the relay's bleed port will close and the control of the vane operator will again be the water temperature control system (figure 13a). The load limit control mechanism could also be called a high limit control or an override circuit.

A manual demand limiting device is also incorporated into the system (figure 13b). This is a manual switch located on the front of the control panel. It provides the operator a means of taking advantage of any reduced load or demand, such as at night or during a cold spell. This reduces the amount of power consumed, saving energy and money. The manual type control can be changed to an automatic control similar to the type used on the modern energy monitor and control system.

The demand limiting equipment used for manual control are a multi tap, variable ratio, current transformer and selector switch. This transformer is installed on one leg of the line side of power to the compressor motor (figure 13b). Through reconnecting of the load limiting relay coil to the various taps of the current transformer, the secondary current through the load limit relay can be varied to limit the load on the motor to 40, 60, 80 or 100 percent of full load. Reconnection is accomplished through the adjustment of the manual demand limit switch S4.

1. What is the function of the manual demand limiting device?
-
-

C. Read the following paragraphs and answer the questions.

Normal Operating Conditions and Control Settings

The normal operating temperatures and pressures are shown in table 1. The normal settings and adjustments for the various system temperature and pressure controls are given in table 2.

Pressure-Temperature Curve for Saturated R-113

Actual condensing conditions can be maintained by using the pressure-temperature curve illustrated in table 3. This is done by plotting the temperature of liquid refrigerant leaving the condenser against condensing pressure.

Refrigerant temperature is obtained by placing a thermometer in the liquid temperature well located in the condenser sump. For well location see figure 7.

If the temperature and pressure lines intersect at a point above the saturation curve, condensing pressure is excessive, indicating air in the condenser. If purging fails to correct this condition, see Trouble Analysis.

If the temperature and pressure lines intersect on the saturation curve, in a normal manner but at a temperature and pressure higher than specified, either the condenser water temperature or flow is not correct or the tubes are fouled. To correct these conditions, see Trouble Analysis.

Table 1 - Normal Operating Conditions

GAGE	NORMAL READING
EVAPORATOR PRESSURE	23-25½ INCHES VACUUM
CONDENSER PRESSURE	5-15 INCHES VACUUM*
PURGE DRUM PRESSURE	15 INCHES VACUUM TO 15 PSI
OIL SUMP TEMPERATURE	130-135 F
COOLED OIL TEMP.	110 F
OIL PRESSURE	12 PSI ABOVE EVAP. PRESSURE

*Condenser pressure is dependent upon the temperature of the condensing water. The pressure should be equal to the saturation pressure of R-113 at a temperature 5° to 10°F above the leaving condenser water temperature.

Table 2. Control Settings

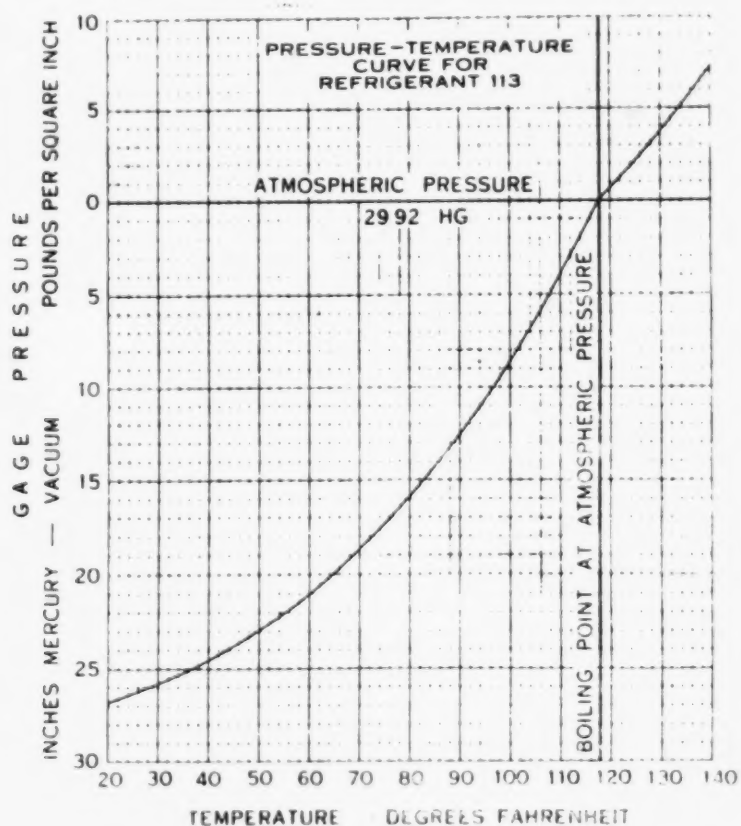
TEMPERATURE CONTROLS			
CONTROL	CUT-IN	DIFFERENTIAL	CUT-OUT
PURGE HEATER TEMP. CONTROL	132 F	8	140 F
MOTOR TEMP. CONTROL (MTC)	110 F	10	120 F
SUMP OIL TEMP. CONTROL (OTC)	*	*	*
BEARING OIL COOLER	**	**	**
LOW TEMP. CONTROL (LTC)	42 F	10	32 F
MOTOR COOLING REG. VALVE	+	+	+
PRESSURE CONTROLS			
HIGH PRESS. CONTROL (HPC)	12" VAC.	10" VAC.	2" VAC.
PURGE PRESS. CONTROL	25 PSI	15 PSI	40 PSI
OIL PRESS. CONTROL (OPC)	8 PSI	4 PSI	4 PSI

* The sump oil temperature control is set to maintain 130-135°F temperature. The differential is fixed at 5°.

**Oil cooler water regulating valve is set to maintain 110°F leaving oil temperature.

+ Set to maintain 85°F leaving water temperature.

Table 3. Pressure Temperature Relation Refrigerant



1. The high pressure cutout on the centrifugal compressor is set for what psi?

2. What is the normal pressure reading for the evaporator?

3. The condenser pressure is dependent upon what temperature?

- D. Read the following paragraph and answer the question.

Purge Drum Water Elimination

Water condensed in the purge drum will float on the surface of the liquid refrigerant. Normally, a separation line can be seen through the purge drum sight glass. When water is observed, use the following steps:

- ___ Turn off purge compressor.
- ___ Open blow-off valve, located on the right end of purge drum.
- ___ Allow valve to remain open until all water has been drained.
- ___ Close valve and return unit to service.

1. Explain the procedures for purge drum water elimination?

SUMMARY

Direct expansion refrigeration systems pump refrigerant directly through the cooling coil, whereas indirect systems pump chilled water or brine through the cooling coil. Indirect refrigeration may be either of the centrifugal or reciprocating type.

There are several companies that manufacture the centrifugal machine. Except for a few engineering differences, these machines are the same. When in doubt about any maintenance or operational procedure, refer to the manufacturer's manuals or handbooks for specific information.

An itemized checklist and operational log must be used and maintained by the operator on duty. Careful inspections will help in correcting malfunctions and give the machine long life and efficient operation.

STOP!

You have completed the directed study assignment in preparation for Day 47.

2-23

ABSORPTION AIR CONDITIONING

OBJECTIVE

To help you learn the scope, application and maintenance of absorption air conditioning systems.

INTRODUCTION

The principle of absorption is more than a century old, but in the past 30 to 40 years, it has not been completely safe, successful or economical. The use of the aqua-lithium bromide system began in 1945. To date, it is the most economical form of comfort cooling for two reasons: water is the best refrigerant on the market and this system converts heat (energy) directly to cooling.

This simplest of all refrigerating machines uses the cheapest, safest and most available of all refrigerants--water. Water is stable, nontoxic, low cost, readily available and has 970 BTUs per pound latent heat of vaporization. Its absorbent is lithium bromide, a salt solution. Most important, large quantities of water are readily absorbed by lithium bromide and easily separated.

Assignment in Preparation for Day 48.

I. MAJOR COMPONENTS AND PRINCIPLES OF OPERATION OF AN ABSORPTION SYSTEM

A. Read the following paragraphs and answer the questions.

The key to understanding the absorption system's operation is to remember the entire unit operates in a deep vacuum. For water to boil in the evaporator at 38°F, a vacuum of approximately 29.65 inches mercury is required. To illustrate the necessity of maintaining these pressures, an increase in pressure of only 0.06 psi in the unit will increase the leaving chilled water temperature 10°F.

This system is used for air conditioning and varies in capacity from three to 500 tons. The absorption unit is in great demand at the present time in larger installations. The machines low operating cost, dependability, minimum maintenance and space requirement, and long life of serviceability, are the major advantages of absorption systems. However, high initial installation and support equipment costs are a disadvantage.

Lithium bromide is but one type of absorption system. The other type of absorption most used today is the aqua (water) ammonia system. It is used in both refrigeration (food storage, etc.) and air conditioning. Ammonia is the refrigerant and water the absorbent. This system operates under high pressures whereas the lithium bromide system must use a deep vacuum.

1. What is the pressure required for water to boil at 38°F?

2. List the advantages of an absorption system.

B. Read the following paragraphs and answer the questions.

Care and Handling of Lithium Bromide

Lithium bromide is nontoxic, nonflammable and nonexplosive. It can easily be handled in an open container. This solution is chemically stable and does not undergo any noticeable change in properties even after years of use in the absorption machine.

Lithium bromide solution is corrosive when exposed to air. If any solution is spilled on exposed parts or tools, it should be wiped off and rinsed with fresh water as soon as possible. Tools should be coated with a light film of oil after rinsing with fresh water to prevent rust.

Empty metal containers used for solution should also be rinsed with fresh water to prevent corrosion. Lithium bromide solution may be irritating to the skin and to the eyes. It should be washed off with soap and water. If it gets into the eyes, wash with fresh water and consult a physician immediately. Lithium bromide is a strong salt solution; do not siphon by mouth.

1. When does lithium bromide become corrosive?

2. What is lithium bromide?

3. What safety precautions should be observed when handling lithium bromide?

C. Read the following paragraph and answer the question.

PUMPS. The pumps that are used with an absorption air conditioner are usually of the centrifugal type. They are equipped with mechanical seals when they are used in a vacuum, as they are on an absorption air conditioner. These seals require a head of water for lubrication so that water rather than air enters the unit in case the seal leaks. On the later model units, the pump and pump motor are hermetically sealed.

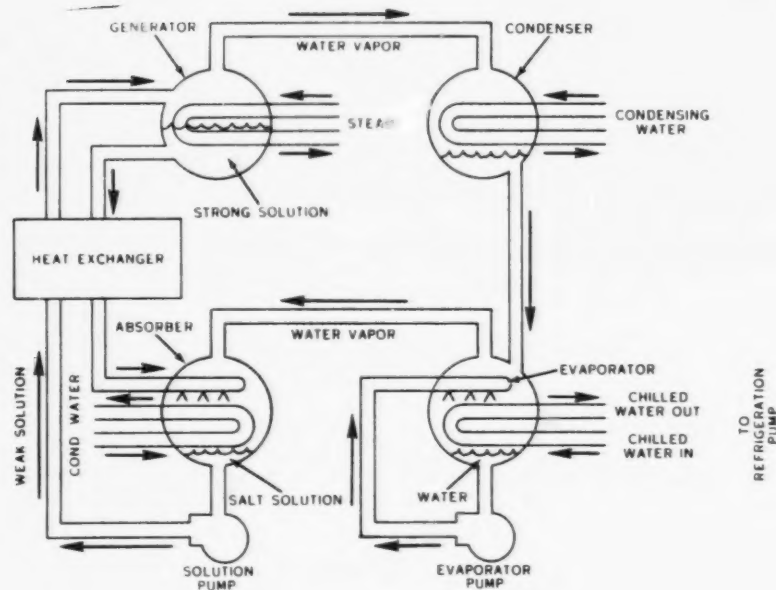


Figure 14. Lithium Bromide Systems

1. Solution and chilled water pumps are equipped with what type of seals?

D. Read the following information and answer the questions.

Absorption System Terms

The following terms describe the major elements of the absorption refrigeration cycle:

1. Absorbent: A substance with the ability to take up or absorb another substance.
2. Concentrated Solution: A solution with a large concentration of lithium bromide and a small amount of refrigerant (water).
3. Dilute Solution: A solution with a large concentration of refrigerant and a small amount of lithium bromide.
4. Heat of Condensation: The heat released when a vapor condenses to a liquid.
5. Heat of Dilution: The heat released when two liquids are mixed (heat of absorption).

1. What is diluted solution?

2. What is a concentrated solution?

E. Read the following paragraphs and answer the questions.

Absorption System Components

Refer to figure 15, Lithium Bromide System.

EVAPORATOR. Chilled water flows through the evaporator tube bundle. It is cooled by the refrigerant being sprayed over the tubes. The chilled water is then pumped to where it furnishes cooling. A refrigerant collection pan, located below the chilled water coils, collects and stores the refrigerant for further cycling.

ABSORBER. The water vapor formed in the evaporator is absorbed by the lithium bromide solution that is being circulated in the absorber. Cooling water from the tower flows through the tube bundle in the absorber removing the heat of absorption, heat of condensation and sensible heat. The lithium bromide must be kept cool to absorb water.

GENERATOR. Lithium bromide solution is pumped from the absorber to the generator where low-pressure steam, or hot water, provides the heat necessary to boil the solution. Boiling removes the water that was absorbed in the absorber and makes a strong solution out of the weak solution. The strong solution then returns to the absorber section. The low-pressure steam or hot water comes from a boiler.

CONDENSER. The water vapor produced in the generator is condensed in the condenser by the relatively cool condenser water flowing from the absorber. A water pan collects the condensed water vapor and returns it to the evaporator section.

HEAT EXCHANGER. A shell and tube heat exchanger in the lines between the absorber and generator transfers heat from the hot, strong solution that is leaving the generator to the weak solution that is entering the generator. This increases the machine's efficiency by causing the solution to be in the generator for a shorter period of time.

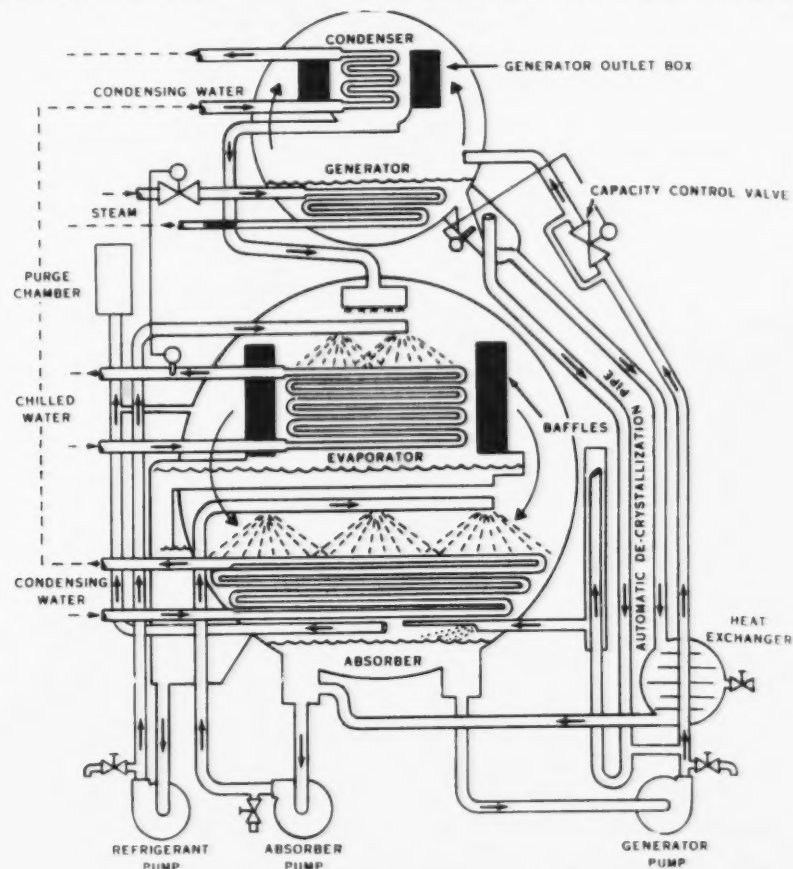


Figure 15. Lithium Bromide System

C-MA-029

1. What is the purpose of routing the condensing water through the absorber?

2. What is the function of the heat exchanger?

- F. Read the following paragraphs and answer the questions.

We can compare the basic absorption cycle with the mechanical compression cycle which you have already learned. Refer to figure 16 as you proceed for the comparison.

To simplify the absorption cycle, we will start the cycle at the outlet of the condenser and not at the compressor as you are accustomed to.

High pressure liquid refrigerant (water) passes from the condenser (1) through an orifice or restrictor (2) and expands into the lower pressure evaporator (3). As the refrigerant (water) is discharged from the orifice into the evaporator (3), the refrigerant (water) is cooled by flash evaporation. The heat will flow from the water circulating through the conditioned space to the liquid refrigerant, vaporizing the refrigerant.

The refrigerant, now a vapor, flows to the absorber (4) where the pressure is the lowest in the system. In the absorber, the vapor is absorbed by the lithium bromide, a salt solution. A combination of absorbent and refrigerant, now mixed, forms a diluted or weak solution. This diluted solution being heavier than the strong absorbent settles to the bottom of the absorber shell where it is pulled out by the solution pump (5). The refrigerant is recovered from the absorbent in this component by distillation. Heat is applied to the solution by means of low pressure steam or hot water boiling out the refrigerant. The strong absorbent solution returns to the absorber and repeats the process. The refrigerant vapor passes to the condenser (1) where it is cooled and condensed by cooling tower water flowing through a tube bundle.

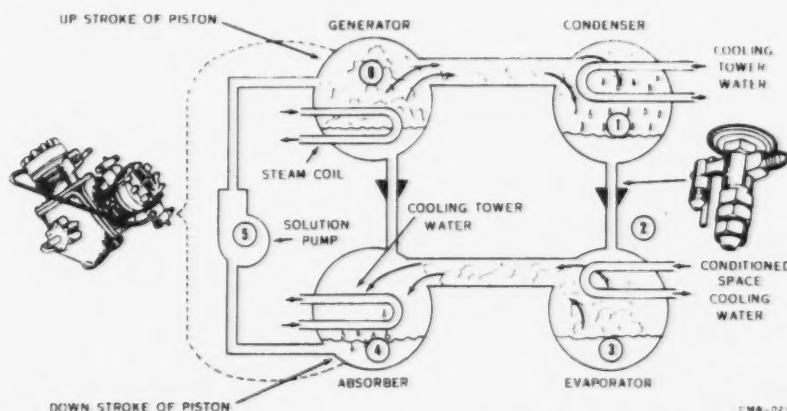


Figure 16. Compression-Absorption Comparison

1. How is the primary refrigerant cooled?

2. Where is the lowest pressure in the absorption system?

3. What is the secondary refrigerant on a lithium bromide system?

G. Read the following paragraphs and answer the questions.

ABSORPTION UNIT CONTROLS. The operation of an absorption air conditioner can be compared to an expensive airplane. When either one is out of control, they do not perform the way they should. It is, therefore, important that you understand the control circuits of the lithium bromide system.

Absorption systems use electric, electronic and pneumatic controls. We will explain the operation of a typical control circuit as you refer to figure 17.

1. What type of control would you find on an absorption?

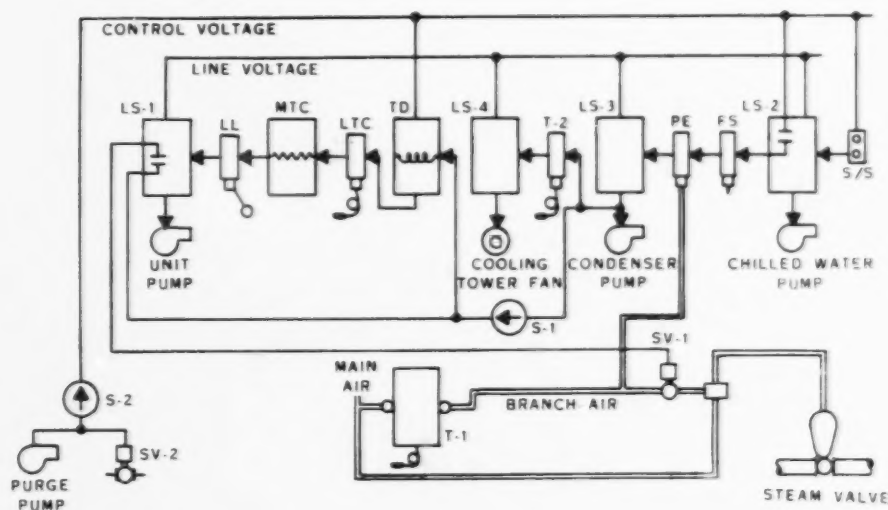


Figure 17. Lithium Bromide Electrical System

H. Read the following paragraphs and answer the questions.

OPERATION. When the main switch is turned on it supplies voltage to the control voltage line. The start-stop switch (S/S) is energized to the start position, starting the chilled water pump through LS-2 which is interlocked with a set of auxiliary motor starter contacts. In series with the auxiliary contacts is a flow switch (FS). Once flow has been established in the chilled water circuit, the flow switch (FS) closes supplying voltage to the pneumatic electric switch (PE).

Upon a rise in temperature in the chilled water supply line, the branch line pressure of the chilled water thermostat (T-1) will rise. The rise in branch line pressure causes the contacts in the pneumatic electric switch (PE) to close, which energizes the condensing water line starter (LS-3) starting the condenser pump. The cooling tower line starter (LS-4) is energized simultaneously through auxiliary contacts starting the cooling tower fan. Once the cooling tower fan is in operation, the cooling tower thermostat (T-2) will cycle the fan on and off to maintain designed cooling water temperature.

Turning the systems on-off switch (S-1) on, energizes the time delay relay (TD). This supplies control voltage to the unit pump's line starter (LS-1) through the normally closed low temperature control (LTC), motor temperature control (MTC) and the liquid level switch (LL) starting the pumps.

Energizing the unit pump line starter (LS-1) closes auxiliary contacts to supply control voltage to the solenoid air valve (SV-1). This opens the solenoid supplying branch pressure to the steam valve.

1. When the main switch is turned on it supplies voltage to the _____

I. Read the following paragraphs and answer the questions.

Systems water temperature changes are sensed by the chilled water thermostat (T-1). The thermostat responds by varying the branch line pressure to the steam valve.

When lower chilled water temperature is sensed by T-1, indicating that cooling is no longer needed, the branch line pressure will decrease causing the pneumatic electric switch (PE) to open. This de-energizes the condenser pump line starter (LS-3) which in turn de-energizes the time delay relay (TD), solenoid air valve (SV-1), and the cooling tower fan line starter (LS-4) stopping the fan. The loss of control voltage to the solenoid air valve (SV-1) causes the steam valve to close, stopping steam to the generator.

Prior to complete shutdown, the unit pumps will continue to operate for approximately seven minutes, under control of the time delay relay (TD), allowing the mixture of weak and strong solution. This equalization of the solution throughout the solution handling portion of the system eliminates the possibility of crystallization during shutdown.

The purge pump and purge pump solenoid valve (SV-2) are energized by closing the purge pump on and off switch (S-2).

1. How is the possibility of crystallization during shutdown eliminated?

Assignment in Preparation for Day 49.

II. OPERATIONAL CHECKS OF AN ABSORPTION SYSTEM

A. Read the following paragraphs and answer the questions.

Checks and Servicing

SOLUTION LEVEL. The solution level in the absorber must be checked. Normal operating level is approximately one-third of the absorber sight glass at full load operation. At partial load operation, the solution level will vary between one-third and two-thirds of the sight glass.

ADD OCTYL-ALCOHOL. With the machine running, add the recommended amount of octyl-alcohol to the solution through the alcohol charging valve in the absorber pump discharge line. The discharge pressure of the absorber solution pump is approximately 5 to 15 inches of vacuum; therefore, even with the pump running, it will be possible to draw the alcohol into the machine. This cleans the outside of the tubes in the generator and absorber and improves their efficiency in transferring heat.

REFRIGERANT LEVEL. The refrigerant level is visually checked through the sight glass located on the evaporator. At a high level, the water may spill over the evaporator tank into the solution in the absorber, causing a loss of operating efficiency. A low level will cause the evaporator water pump to surge (cavitate) when it is running. A low refrigerant level results in less refrigeration effect.

1. How is the correct solution level determined?

2. How is the refrigerant level determined?

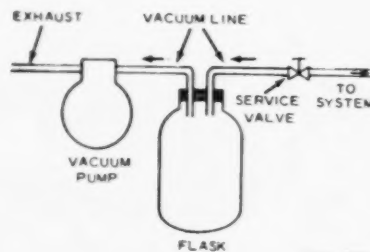
B. Read the following paragraphs and answer the questions.

SOLUTION CONCENTRATION CHECK. A common characteristic of the lithium bromide absorption air conditioner is that the lithium bromide solution will crystallize or solidify under certain conditions. To solidify or crystallize means the absorbent changes from a liquid to a solid state. Solidification will cause the unit to stop, but will not cause permanent damage to the unit. After the solution is de-solidified, the unit may be placed back in operation. To de-solidify, you would dilute the solidified area with system liquids and, if necessary, apply heat. One method used to determine solution concentration (percent of lithium bromide to water) is as follows. We will use some figure to form an example along with the diagram in figure 18. Use 100° for the temperature of the refrigerant leaving the condenser. Follow the 100° line upward until it gets to the diagonal waterline, mark the chart at this point. Use 160° for the temperature of the solution leaving the generator. Using the mark that you have already made on the chart, go horizontally to the right until you intersect the 160° vertical line. At this point, read the solution concentration from the diagonal lines, it would be 65 percent.

REMOVING REFRIGERANT OR SOLUTION. When it is necessary to remove a part or all of the system charge, you may use one of the two methods below. On some units, the pump discharge pressure is above atmospheric. On these units, just open a valve on the pump discharge and drain out the quantity desired. On units that all pressures are below atmospheric, remove the charge using the following procedure. Refer to figure 17a.

- Connect vacuum hoses to service valve, flask and vacuum pump.
- Operate vacuum pump to bring flask pressure below absorption unit pressure.
- Open service valve and solution or refrigerant will flow into flask.

Still another method of removing solution or refrigerant is to pressurize system with R-13 or nitrogen above atmospheric pressure and blow the charge into a suitable container. Again, refer to manufacturer's procedures manuals.



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Figure 17a. Removing Refrigerant

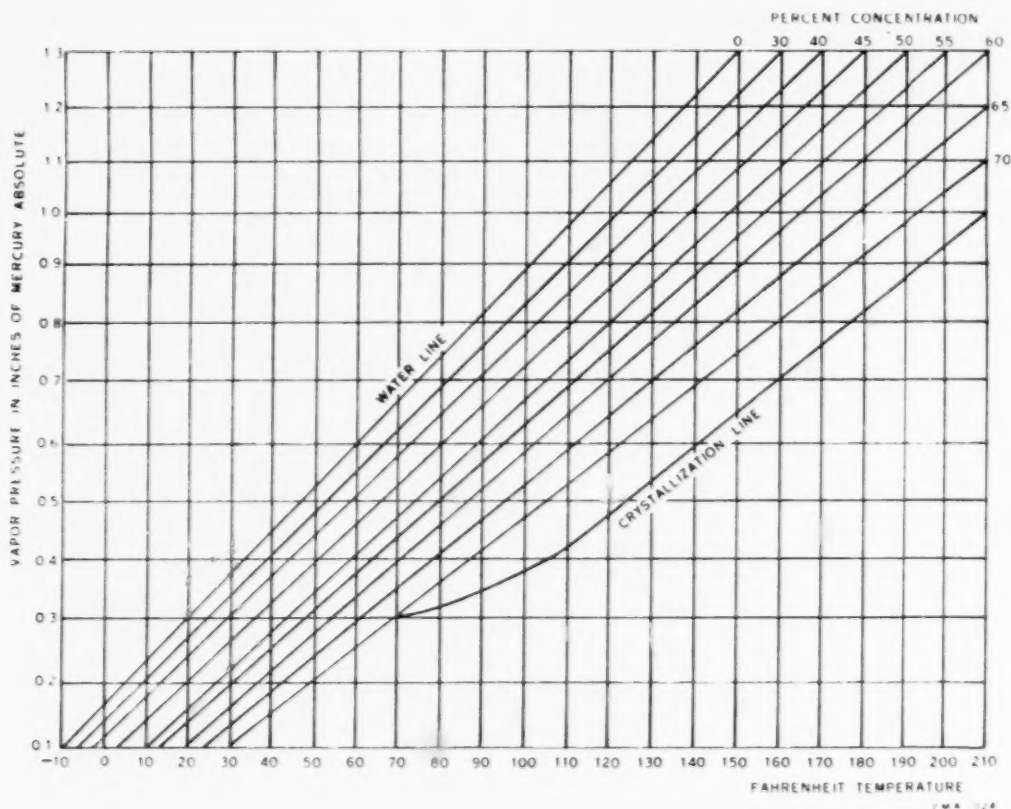


Figure 18. Lithium Bromide Solution Chart

1. What is a common characteristic of the lithium bromide absorption air conditioner?

2. Explain the procedures for removing refrigerant or solution.

- C. Read the following paragraphs and answer the questions.

LEAK CHECK. Before starting the unit that has the absorbent and refrigerant in it, the vacuum should be checked. Air may have entered the system during the charging process or through a leak while it was shut down. To do this, take a manometer reading (figure 19a) and the temperature of the machine room. With these known, plot the pressure temperature curve as shown in figure 19b. If the plotted pressure reading is more than .1 inch of mercury higher than the pressure located on the curve, there is air in the unit. If this condition recurs on the next two or three startups, the unit should be shut down as soon as possible and tested for leaks. Air (oxygen) in the presence of lithium bromide salt will cause corrosion inside the unit and shorten equipment life.

DRY VACUUM TEST. After completing the annual maintenance, the system should be checked for leaks. Evacuate the system until an absolute pressure of at least .03 inches of mercury is read on the manometer. Record this reading. Check the manometer again 24 hours later. If there is no loss of vacuum, then charge the system with solution and refrigerant (water). If the unit does not meet the vacuum requirements, it should be tested for leaks with a leak detector.

To test the system in this manner, it is necessary to first charge the unit with refrigerant R-12 and water pumped nitrogen. Charge the unit with R-12 to 5 psi or 10 inches of mercury, continue charging with nitrogen to about 18 psig. When the charging operations are completed, test the system for leaks with a leak detector. Make permanent repairs to any leaks found.

On newer systems, pressurize with R-13 is sometimes recommended because R-13 is not soluble with water. Leak check the system with an electronic leak detector. Out in the field, the service specialist will refer to manufacturer's procedures for the method recommended for a particular unit.

1. What is the effect if air is in the lithium bromide salt?

2. Explain the procedures to do a dry vacuum test on a lithium bromide system.

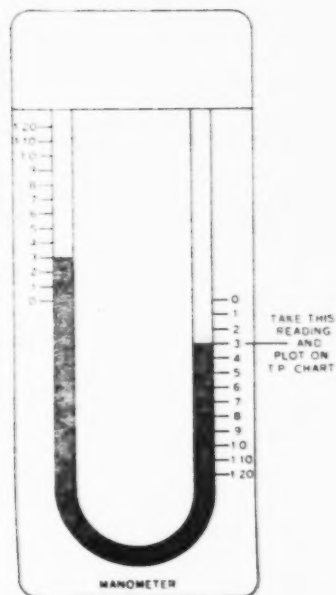


Figure 19a. Manometer

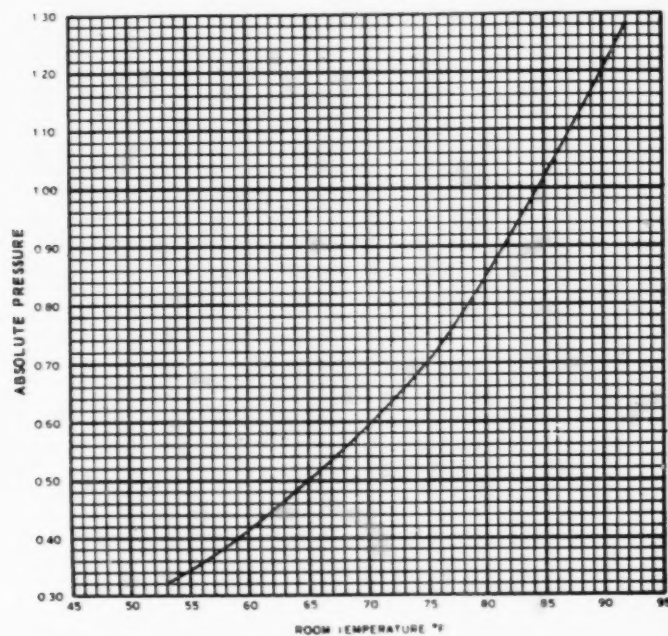


Figure 19b. Temperature-Pressure Chart

D. Read the following paragraphs and answer the questions.

CHARGING WITH REFRIGERANT AND SOLUTION. After all maintenance is completed and the system passes a satisfactory vacuum test, the unit is ready to be charged with solution and refrigerant. To charge with refrigerant, connect a vacuum pump to the purge connection and let it run for several minutes to lower the absolute pressure of the system.

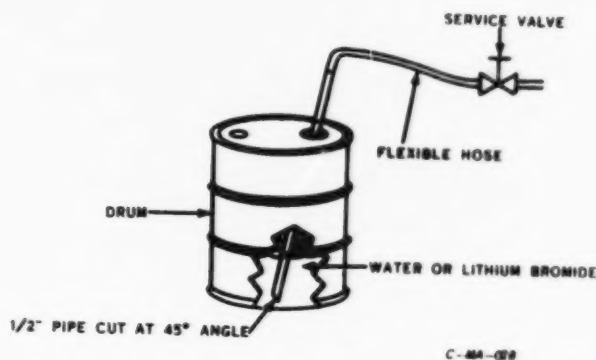


Figure 20. Charging Refrigerant or Solution

Solution Charging:

1. ☐ Connect flexible hose to 1/2-inch pipe. Cut end of pipe at a 45° angle to prevent pipe from sealing itself on bottom of drum. (See figure 20) Fill both pipe and hose with water.
2. ☐ Insert pipe into drum and connect flexible hose to solution pump service valve.
3. ☐ Open service valve. Charge the system with the amount specified by the manufacturer for the particular unit. Caution should be exercised to never let the liquid level in the drum drop below the end of the pipe. If this should happen, air would be drawn into the unit.

Refrigerant Charging:

1. ☐ Same procedure as solution charging.
2. ☐ Insert pipe into drum and connect flexible hose to refrigerant pump service valve.
3. ☐ Same procedure as solution charging.

1. Explain the procedures for charging the lithium bromide system with refrigerant.

2. Explain the procedures for charging the lithium bromide system with solution.

- E. Read the following paragraphs and answer the questions.

PURGE UNIT. The purge unit is a necessary part of the machine. It removes, stores and discharges to the atmosphere, all air and noncondensables accumulated in the machine. It is composed of three basic sections:

— Suction Chamber. Weak lithium bromide solution is supplied to this chamber from the discharge of the solution pump. As the solution cools, a low pressure area is formed. Noncondensables are then drawn into the chamber from the absorber. Since the absorber is in the lowest vacuum, all air and noncondensables will collect there.

— Return Chamber. The lithium bromide solution and all noncondensables flow into the return chamber. In this chamber, the air and noncondensables bubble up to the storage chamber. The solution is returned to the absorber through a return valve.

— Storage Chamber. The noncondensables are accumulated in this section until the exhaust cycle then they are discharged to the atmosphere.

1. What is the purpose of the purge unit?

2. What are the three basic sections of the purge unit?

STOP!

You have completed the directed study assignment in preparation for Day 49.

ABSORPTION MACHINE LOG

Strong Sol Lvg Conc	-°F		
Strong Sol Lvg HX	-°F		
Intermediate Sol Abs Spray	-°F		
Dilute Sol Lvg Abs	-°F		
Dilute Sol Lvg HX	-°F		
Condensing	-°F		
Refrigerant	-°F		
Chilled H ₂ O in	-°F		
Chilled H ₂ O out	-°F		
Cooling H ₂ O in Abs	-°F		
Cooling H ₂ O out ABS	-°F		
Cooling H ₂ O out Cds	-°F		
Solution Level	-°F		
Refrigerant Level-Spill	Yes/No		
Strong Solution Concentration	%		
Dilute Solution Concentration	%		
Spread			
Steam Press in	Lbs		

Remarks and Comments: _____

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OPERATIONAL ANALYSIS CHART

PROBLEMS	CAUSE	REMEDY
1. Lithium Bromide Solidifies at Startup	a. Condenser water below designed temperature. b. Air in machine. c. Steam pressure too high.	a. Reset tower water bypass valve. b. Purge system. c. Reset pressure regulating valve.
2. Lithium Bromide Solidifies During Operation	a. Condenser water below design temperature. b. Improper purging. c. Salt buildup on absorber tubes and spray nozzles.	a. Reset tower water bypass valve. b. Check purge system. c. Add octyl-alcohol.
3. Low Capacity	a. Air in machine. b. Scale in condenser tubes. c. Not enough solution concentration in generator. d. Refrigerant overflow from evaporator to absorber. e. Capacity control valve returning too much weak solution back to absorber.	a. Repair leak and/or purge system. b. Remove scale and treat water. c. Check amount of steam flow and pressure. d. Remove part of refrigerant charge. e. Reset control to correct temperature.
4. Machine Shuts Down on Safety Controls	a. Motor overload opens. b. No load when diluting.	a. Find reason and reset overload. b. Check temperature controller and reset if needed.
5. Solidification During Shutdown	a. Dilution cycle not long enough. b. No load when diluting.	a. Lengthen dilution cycle to at least 7 minutes. b. Open reclaiming valve to put load on machine.
6. Air Leak into Machine	a. Any connection, fitting or component exposed to atmosphere may be cause.	a. (1) Check for leakage at valves. (2) Check vertical purge.
7. Loss of Vacuum at Shutdown	a. Air leakage into machine.	a. (1) Check for leakage at valves. (2) Perform leak check.
8. Failure to Keep Machine Purged	a. Air leakage into machine. b. Vertical purge not removing noncondensables properly.	a. Perform leak check. b. (1) Check rate of purge. (2) Purge solution solidified. De-solidify.

SUMMARY

The absorption system operates on the principle of one material being able to absorb or take up the vapors of another substance and thus reduce the pressure.

The absorption refrigeration unit consists of a generator assembly and an absorber assembly. The condenser and generator are combined in the generator assembly, or upper shell of the unit; while the evaporator and absorber are combined in the absorber assembly, or lower shell of the unit. The control panel is located on the side of the absorber assembly. The other minor units, such as the absorber sight glass, solution heat exchanger and the solution pump, are usually mounted between the supporting legs of the absorption unit.

CYLINDER UNLOADERS AND HUMIDITY CONTROLS

OBJECTIVE

When you have completed this unit of instruction on the 8.5-ton reciprocating trainer, you will be able to:

- Locate, identify and state the functions of safety controls and major components.
- Locate operational and capacity controls, state their functions and adjust for proper operations.

INTRODUCTION

The successful operation of radar equipment, communications networks, missile guidance, automatic data processing computers, and other applications required equipment cooling and ventilation systems which cannot stand wide temperature and humidity variations.

The control of temperature may be required to within $\pm 1^\circ\text{F}$, and the humidity tolerance within $\pm .5$ percent. Relative humidity control usually allows a greater tolerance but must be low enough to minimize rust and corrosion while high enough to prevent static electricity charges from arcing.

To control the temperature, humidity and ventilation in large equipment applications, many controls must be used to effect the desired conditions. Combinations of electrical, pneumatic and electronic controllers, and controlled devices work as a unified team to produce the successful system operation.

The checking of system efficiency against designed performance data is just as important as checking the calibration and adjustment. In fact, it should be a primary consideration.

Compressor capacity control can be achieved in numerous methods--ranging from pressure switches to complex hydraulic systems, depending upon the system in use.

In all fields of air conditioning, the design conditions will have variable limits. The usual extreme conditions exist when the temperature is over 80°F or below 70°F , and if the humidity is less than 30 percent or more than 50 percent. Maintaining the exact range is often difficult but can be achieved with properly operating systems.

Assignment in Preparation for Day 50

I. CYLINDER UNLOADERS

- A. Read the following paragraph and answer the question.

FUNDAMENTALS OF DIRECT EXPANSION AIP CONDITIONING EQUIPMENT

Direct expansion is a descriptive term. It describes the type of refrigeration system used. Evaporators are sometimes called expansion coils. When the evaporator cools the air, the system is called direct expansion. If a secondary refrigerant (brine or chilled water) is used to cool the air, the system is known as indirect expansion.

1. Explain a direct expansion system.

B. Read the following paragraph and answer the question.

Most large air conditioning systems use compressors with some type of capacity control. This capacity control is usually accomplished by holding one or more of the suction valves open when operating under reduced load. Unfortunately, the capacity of a thermostatic expansion valve cannot be controlled that easily. With the capacity of the expansion valve at a relatively constant value, it becomes oversized when the capacity of the compressor is lowered. However, within reasonable limits, a thermostatic expansion valve will adjust to a low-load condition and still maintain the required refrigerant control. Actually, smooth valve control is not necessary to reduce loads because full evaporator capacity is not required under these conditions.

1. How is capacity control accomplished?

C. Read the following paragraphs and answer the questions.

CAPACITY CONTROL

Cylinder Unloaders

This method of compressor capacity control is used almost universally on large multiple cylinder compressors driven by alternating current electrical motors. A device installed in the compressor holds the suction valve of each cylinder open as the load decreases. Assume that a 5-ton load is being cooled with a three-cylinder compressor. When the unit starts, there is only one cylinder operating. Assume the theater is cool. The other two cylinders have their suction valves automatically held open. As people come into the theater, the air conditioning load increases, and number two cylinder is automatically brought into operation. The same thing happens for cylinder three, until maximum load is reached. After the sun goes down, the heat load decreases. Number three cylinder is then automatically unloaded by holding the suction valve open again. The same thing happened for cylinder two. As the need for refrigeration continues to reduce, number one cylinder reduces the low side pressure to a predetermined point, and the unit turns off. With this system, there is very little on-off operation. The compressor runs continuously and is producing refrigeration in varying amounts as required. A system of this type will maintain very close temperature control. No matter how many cylinders a compressor has, it will have at least one cylinder loaded all the time.

Cylinder unloading may be accomplished electrically, pneumatically or hydraulically. Hydraulic unloaders are the most commonly used. A typical hydraulic unloader mechanism consists of four main units: unloader sleeve, unloader power element, hydraulic relay and capacity control valve.

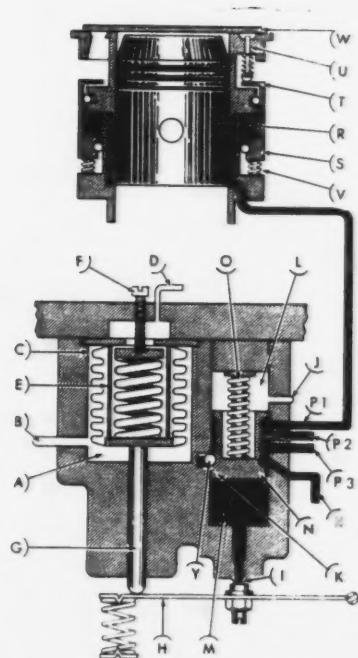


Figure 21. Cylinder Unloader Assembly

1. How may cylinder unloading be accomplished?

2. How many cylinders will be loaded at all times?

- D. Read the following paragraphs and answer the questions.

OPERATION: The operation can be traced in figure 22. The pressure from the crankcase is fed through a surge chamber which changes the pulsating pressure to a stabilized oil flow to the capacity control valve (1). As the increase of pressure enters the valve, an internal bellows is expanded; and the push rods attached to the needle and seat assembly pull the needle toward the seat. This action increases the control oil pressure. The increase of pressure in the crankcase is also passed through the oil pump to the hydraulic relay (2).

NOTE: This pressure is true oil pressure plus suction pressure.

The increased oil pressure will bleed through the port in the end of the relay piston and force the piston to move one notch against the ball and spring assembly for each increase of 2 psi. For each increase of 2 psi, the repositioning opens a port leading to an unloader power element (3).

NOTE: There is one less cylinder unloader power element than total number of cylinders; this means that one cylinder will be fully loaded at all times.

As the unloader power element (3) has the increased power applied, it is forced against the piston face, opposing the spring pressure and pushing up on the lifting fork assembly (4). The fulcrum action causes the lifting fork to drop, which allows the unloader sleeve (5) to drop. The dropping action of the unloader sleeve allows the push pins (6) to fall against the face of the unloader sleeve allowing the suction disc (7) to seat on top of the cylinder and load the cylinder.

As the pressure decreases in the crankcase, the decrease through the capacity control valve (1) causes the bellows to contract and the push pins (9) push the needle away from the seat, decreasing the control oil pressure (10). This decreased control oil pressure will allow the spring pressure to reposition the piston, closing off feedline ports to the unloader power elements one notch against the ball and seat assembly (11) for each 2 to 2.5 psi change in pressure. As the pressure is no longer being applied to the unloader power element (3), the internal spring pressure forces the excessive oil to return by gravity feed to the crankcase. The fulcrum action of the lifting fork (4) forces up on the unloader sleeve (5). This lifting action pushes the lifting pin (6) against the disc type suction valve (7) raising it off the seat, unloading the cylinder.

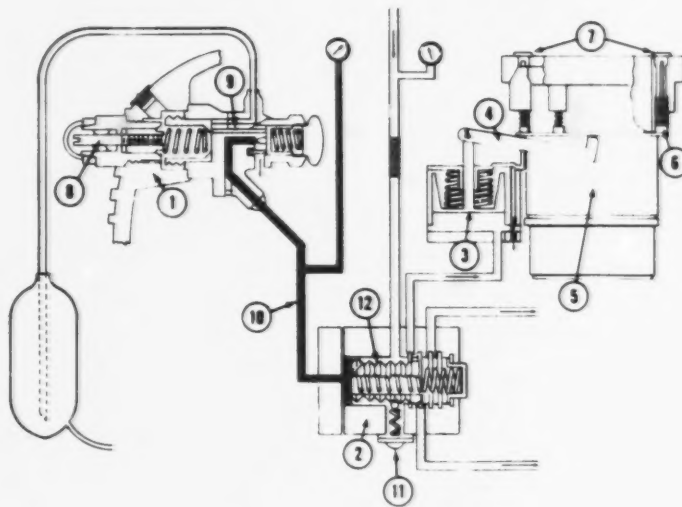


Figure 22. Cylinder Unloader Circuit

1. How many cylinder unloaders' power elements would be found on a system?

2. What pressure does the unloader power element oppose?

E. Read the following paragraphs and answer the questions.

ADJUSTMENT. The capacity control mechanism must be adjusted to maintain a balance between the load and compressor capacity. This adjustment is made by turning the external adjustment stem on the capacity control valve. Turning the adjusting stem clockwise (in) unloads the cylinders. Turning the adjusting stem counterclockwise (out) loads the cylinders.

The ideal setting of the capacity control valve is achieved when the first cylinder unloads at a pressure of 3 psi below the design suction pressure. The capacity control valve loads and unloads cylinders in steps to balance the compressor capacity with the heat load. The compressor must be completely loaded before the capacity control valve can be correctly set. If it is impossible to fully load the system before setting the control valve, adjust the valve to give a minimum of cycling and make the final adjustment when the system is fully loaded. A step-by-step procedures for adjusting the capacity control mechanism is contained in the workbook exercises that are used with this study guide.

1. Turning the adjusting screw clockwise does what to the cylinder?

2. What is the ideal setting of the capacity control valve?

TROUBLE ANALYSIS

Determining the cause of a malfunction in an air conditioning system is usually much more difficult than repairing it once the trouble is located. The following is a trouble analysis chart which may be an aid to you in finding possible troubles.

TROUBLE	PROBABLE CAUSE	REMEDY
Low Suction Pressure	Cylinder unloader out of adjustment	Adjust
	Restricted liquid line	Clear restriction
	Insufficient airflow	(1) Clean filter (2) Tighten air handler belt
	TEV power assembly lost charge	Replace TEV
High Suction Pressure	Cylinder unloader out of adjustment	Adjust
	Excessive load on system	Close doors
Low Discharge Pressure	Outside air temperature too low	Consider possibility of capacity for condenser
	Fan pressure switch out of adjustment	Adjust
High Discharge Pressure	Fan pressure switch out of adjustment	Adjust fan switch
	High outside temperature	Check condenser for cleanliness
	Dirty condenser	Clean condenser
	Noncondensables in system	Purge
Abnormal Noises	Low compressor oil level	Add oil
	Loose belt	Tighten belt
	Broken motor mounts	Replace mounts
	Vibrating refrigerant lines	Anchor lines
	Bearings on fan or motors bad	Replace bearings or replace complete fan or motor
	Compressor slugging	Install accumulator

Trouble Analysis Chart

II. TEMPERATURE AND HUMIDITY CONTROL

A. Read the following paragraphs and answer the question.

Application of Series-90 Control

It is often desirable to control the temperature of an equipment cooling space by controlling the amount of air that circulates across a direct expansion (DX) coil. Figure 23 is a diagram of this application.

When the room temperature cools below the set point, the room thermostat wiper moves toward the blue lead B. This causes more current to flow in the right circuit of the resistance bridge, energizing the CCW winding of the face and bypass damper motor. The face damper will close and the bypass damper open until the resistance bridge circuits are again in balance.

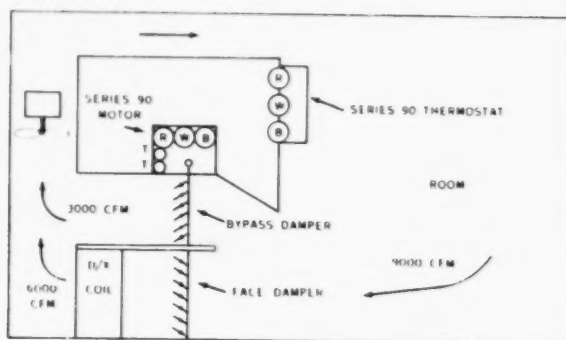


Figure 23. Face and Bypass Damper Temperature Control

1. Explain how the temperature of the cooling space is controlled using a series 90 control.

B. Read the following paragraphs and answer the question.

APPLICATION OF TEMPERATURE AND RELATIVE HUMIDITY CONTROLS

Applications of automatic control systems range from simple domestic temperature regulation to precision control of industrial processes. Automatic controls can be used wherever a variable condition must be controlled. That condition may be pressure, temperature, humidity or rate and volume of flow; and it may exist in a liquid, a solid or a gas.

In the following paragraphs, we will see an application of controls. These controls are employed to maintain the relative humidity and temperature in a space.

Control of Temperature and Relative Humidity (RH)

CONTROL. The controls used for control of the system consist primarily of Room Thermostat T-1 and Humidistat H-1. The compressor capacity control has been adjusted so that all the cylinders are loaded. The bypass dampers are closed as indicated, and the reheat coil is closed. The maximum sensible and latent heat load possible has been placed on the system to produce a room condition of 75°F and 50 percent RH.

CONTROL ADJUSTMENT. Place the normal room load on the system. Adjust the set point of thermostat T-1 to 75°F and high limit humidistat H-1 to 50 percent maximum. Adjust the capacity control (Cylinder Unloaders) so that one cylinder will be unloaded when the ADP is 40°F. Observe the operation of the system and trim the controls, as necessary, to maintain the desired room conditions.

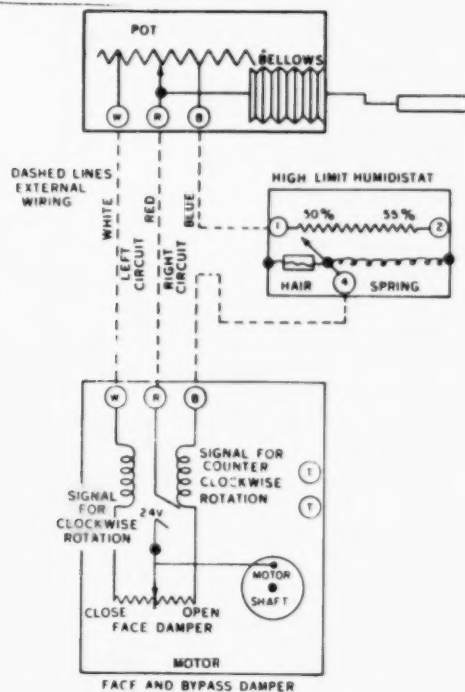
1. What controls are used for the control of the system?

C. Read the following paragraphs and answer the question.

High Limit Humidistat

In most equipment cooling systems, we do not control humidity at a specified figure, but are given a high limit such as 50 percent which we must not exceed. This can be accomplished very easily by inserting a series-90 high limit humidistat in a basic series-90 circuit (see figure 24).

Support that the maximum humidity allowed in the equipment cooling system is 50 percent, and the thermostat is set with the face and bypass half open. As long as the humidity remains below 50 percent, the humidity pot wiper will remain at 1. When the humidity in the room goes above 50 percent, the humidistat hair will become longer, causing the humidistat pot wiper to move toward 2. This movement adds more resistance to the right series-90 circuit. More current will flow through the clockwise relay winding; the damper motor will turn clockwise, opening the face damper. With more air going over the DX coil, more moisture will be removed from it, and eventually the room humidity will decrease. The high-limit humidistat will override the thermostat and cause the face damper to open more than the thermostat wants it to. Naturally, if the face damper is open more than the thermostat is calling for it to open, the room temperature will drop below the desired value. This is corrected by adding a reheat steam or hot water coil operating on command of a second pot in the room thermostat. A complete system is shown in figure 24. This system will maintain both the temperature and humidity within the limits of an equipment cooling system. Figure 24 shows the wiring that would have to be accomplished by a refrigeration specialist in connecting the complete control system.



Series-90 High Limit Humidity Control

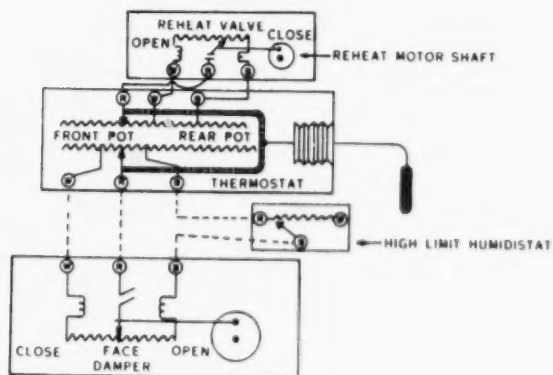


Figure 24. Complete Temperature and High Limit Humidity Control

1. How is moisture removed from the condition space?

D. Read the following paragraphs and answer the questions.

A schematic of a typical equipment cooling system is shown in figure 25. The thermostat controls the temperature of the air in the equipment cooling space. This is done by modulating the face and bypass dampers. The face and bypass dampers are so arranged that they operate opposite each other. When the face damper is opening, the bypass damper is closing. The face damper will be 1/4 open when the bypass damper is 3/4 open. When the temperature is at set point, both face and bypass dampers will be in the half position. Half position can be called either half open or half closed. When the space becomes warmer than the set point of the thermostat (76°F in this example), the thermostat will signal the damper motor to open the face damper slightly more than 1/2. Opening this damper will cause more air to pass over the direct expansion cooling coil. The supply air will become cooler, thereby lowering the room temperature back to 75°F.

With the space temperature at 75°F, the thermostat directs the face damper to be exactly 1/2 open. Now let us assume that the humidity in the equipment cooling space goes above the high limit set point of 50 percent to 51 percent. The high limit humidistat (H-1) will override the thermostat and command the face damper to open more than 1/2. The DX coil, having a mean surface temperature (apparatus dew point) of about 40°F, will remove more grains of moisture from the circulating air and in time will lower the space relative humidity.

Because the humidistat opened the face damper more than the thermostat wants it to, the space temperature will drop below 75°F. In this case the thermostat directs the reheat coil to furnish heat to the supply air so that the space will be exactly 75°F.

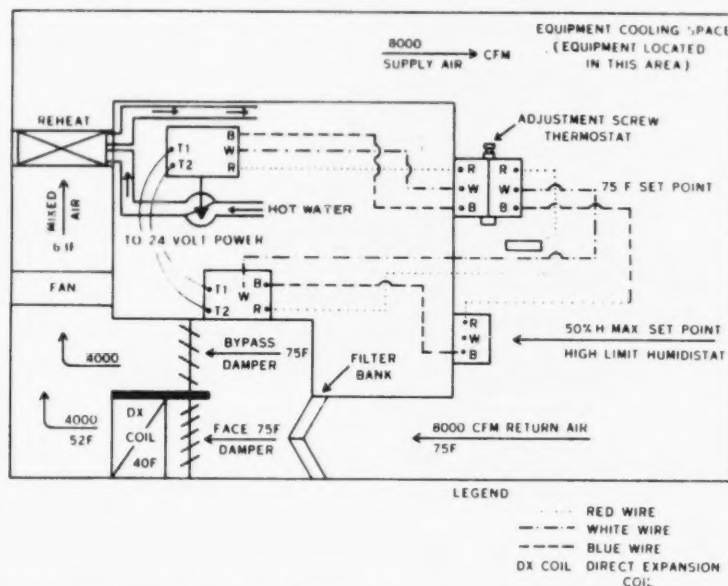


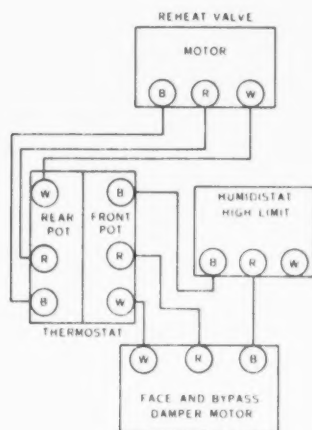
Figure 25. Schematic of a Typical Equipment Cooling System

1. How does the thermostat control the temperature of the cooling space?

2. Explain the operation of the high limit humidistat as the R/H exceeds 50%.

E. Read the following paragraph and answer the question.

In summing up the actions of the thermostat and high limit humidistat, the thermostat controls the face and bypass dampers and reheat coil. The humidistat has more authority than the thermostat in controlling the face and bypass dampers and can override the thermostat in causing the face damper to open wider than usual. The humidistat has no control of the reheat coil. In this manner, both temperature and maximum humidity requirements can be maintained in an equipment cooling space.



NOTE: ALL WIRING SHOWN IS 24V AC.

Figure 26. External Wiring of Temperature and High Limit Humidity Control System

1. Which control has more authority?

F. Read the following paragraphs and answer the questions.

Low Limit Humidity Control

As mentioned previously, in some equipment cooling systems we do not control humidity within a close tolerance.

Now that you are familiar with high limit humidity control and how to accomplish it, low limit control (below 45 percent) will be discussed.

Low limit humidity is controlled by another humidistat (H-2), which can control either a modulating steam valve or spray nozzles to add moisture to the conditioned space.

The low limit humidity control loop has its own step down transformer and there is an airflow switch in series to the line side of the transformer. With this type setup, it is impossible for the low limit humidity loop to function unless the air handler is operating. The system is designed this way to prevent the injection of steam or spray water into the air handler while the air handler is off.

1. What does the low limit humidistat control when R/H falls below 45%?

2. How is moisture added to the air of controlled space?

STOP!

You have completed the directed study assignment in preparation for Day 50.

Assignment in Preparation for Day 51

- A. Study and complete ATC SG E3ABR/OBR 00001.
- B. Given a source document, identify the vulnerabilities associated with the refrigeration and cryogenics career field with no more than two errors.

INFORMATION

Being assigned to the refrigeration and air conditioning shop in civil engineering does not involve too many security precautions. After all, what could be classified about a water cooler, a household refrigerator or even a commercially-made air conditioner? But think again! Where are these units located? Or better yet, where could they be located? If they are in your base dining facility or your office, no problem; but these units are not always located in an unsecure area. They could be in a very sensitive area. Keep in mind that even though these units themselves are not classified, their physical location might be.

There are those of you being assigned to a missile base, Minot, Grand Forks, Little Rock, Malmstrom or Davis-Monthan. But you say, my assignment sheet reads Civil Engineering, I'm not going to be in missiles. Who do you think the missile squadrons call when they have a problem their people cannot handle? That's right, they are going to call the Base Civil Engineering Squadron. On most bases, civil engineering provides direct support for air conditioning and refrigeration equipment. So, as you can now see, you may be involved with missiles and the security vulnerabilities involved with that type of weapon system.

The first time you are dispatched to a missile complex you will probably be curious, looking around and asking questions. Maybe your questions will be answered and maybe not. In any event what you see or hear must be kept to yourself. This goes as far as: how far it is to a specific site, in which direction or how many missiles are located there. It is easy to say, everyone knows how far it is out there. The farmers even know because it is on their land. Maybe they don't know. Or if they do, they might not know the exact location.

Then there is always the building where they store the missiles and warheads and these buildings are going to be air-conditioned. There is Real Property Installed Equipment (RPIE), and civil engineering personnel must maintain it. You could make a slip and mention how critical the temperature and humidity has to be. All of this could be information the enemy could use to determine how they could inflict damage to our missile force during an armed conflict anywhere in the world.

Now, how about those of you who have nothing to do with missiles or missile bases? You are still saying what could be classified on my base? Just about every base will have a communications center. All their equipment has to be air-conditioned. Granted, the air conditioning equipment itself is not classified, but to work on it you are going to be required to be inside the building and around classified equipment.

Have you ever heard of the Command Post on this base? That's right, every base will have one. They will also have the Base Headquarters building and in most cases a Control Tower and Radar Approach Control (RAPCON) building. These all have some form of classified material or equipment.

Then some of you are being assigned to a unit that might require a security clearance--such as a Mobile Communications Squadron, Radar Squadron or even a Security Services Base, such as Goodfellow Air Force Base. In these areas you will constantly be involved with security precautions and their vulnerabilities.

Keep in mind also, that security precautions do not just apply while you are working on the base. They also apply off base, during your free time. Getting together with a group of friends and relating different experiences or troubles encountered on a job could relate to classified information to the trained ear. Remember, "Big Brother" is watching and, more important, listening.

As you can see, just because you are being assigned to a Civil Engineering Squadron, you will still be involved with the vulnerabilities of security.

OPERATIONS SECURITY

Terms Explained

a. Operation. For the purpose of this regulation, an operation refers to any military activity, exercise, function, project, program, or event which requires the protection of information to deny a potential enemy either a tactical or strategic advantage. Specifically included are any support activities (logistics, research and development, training, and others) which may contain intelligence indicators that would reveal operational capabilities or intentions when properly collated and analyzed.

b. Operations Security (OPSEC). The protection of operations resulting from the identification and subsequent elimination or control of intelligence indicators susceptible to hostile exploitation. The purpose of OPSEC is to prevent the disclosure of information containing intelligence indicators that can be used to degrade operational effectiveness.

c. Intelligence Indicator. An item of possible intelligence value that can provide information about capabilities and intentions when properly interpreted.

History and Background of OPSEC

The first formal OPSEC program was developed to protect Southeast Asia operations. The OPSEC survey proved to be a valuable tool in the overall OPSEC program; it provided a systematized means to identify and eliminate enemy sources of information.

Write the missing word(s) in the blanks below:

1. The first formal OPSEC program was developed to _____
_____.
2. The _____ proved to be a _____ in the overall OPSEC program.

The success or failure of most major combat operations depends on the element of surprise. Before an operation can start, personnel must be assembled, equipment and transportation massed, and numerous other activities completed. Usually, definite patterns of behavior can become warning signs to enemy intelligence collectors.

3. The success or failure of most major combat operations depends on the _____
_____.
4. Usually, definite _____ or actions are followed, and these _____ can become _____ to enemy _____.

Attempts to gain information about planned operations is not new, these activities are age-old practices. The activities of opposing forces are constantly monitored to obtain indications of planned operations, because such forewarning may provide time to institute countermeasures to reduce or eliminate the advantage of surprise.

5. Indications of planned operations can be obtained because the _____ of _____ are continually _____.
6. _____ may provide time to institute _____ to reduce or eliminate the _____.

The need for overall security is not limited to major combat operations, but is also important for any operation, including peacetime maneuvers. In the case of combat operations, prior knowledge of the enemy can give him time to take defensive actions which will cause the operation to be ineffective or fail completely. Peacetime operations which are known to a potential enemy can give him an advantage militarily and diplomatically.

7. The need for security is evident concerning major combat operations, however, it is also important for _____.

8. When an enemy has prior knowledge of an operation it gives him _____.

9. Peacetime operations security is important since disclosure of plans gives an enemy _____.

Studies in intelligence show how information can be gathered by an enemy without the violation of security rules by our forces. Such actions as posting flight schedules, the establishing of flight patterns, or increased observable activities can give an enemy insight into a pending operation. Finally, unclassified communications, when gathered and compiled by a trained agent, can be very detrimental to the success of an operation. Awareness of unclassified leaks of information, and their contribution to the failure of classified operations, must be maintained constantly if we are to have a good OPSEC program.

10. Intelligence studies show how information can be gathered by an enemy _____.

11. _____ contribute to the failure of _____.

Relationship of OPSEC to Other Security Programs

Communication Security (COMSEC). As you learned previously in your study of COMSEC, communications are absolutely essential to the success of any operation. The need for communication security cannot be overstressed. The relationship of COMSEC and OPSEC is very real and cannot be separated.

12. _____ are absolutely _____ to the _____ of any _____.

Any type of communication can violate OPSEC; official or unofficial, classified or unclassified, written, transmitted, or face to face communications all require control in order to have an effective OPSEC program.

13. What kind of communications are vulnerable to interception or compromise?

COMMON OPSEC VULNERABILITIES

Operational Indicators

- a. Sterotyped sequences of events comprising various phases of the operation.
- b. Coordination with other agencies that do not have proper safeguards for sensitive information.
- c. Submission of unclassified reports at specific intervals to specific units or levels of command.
- d. Sterotyped patterns of flight activity at a particular location.

Write in the letter of the operational indicator that best fits:

1. Servicing all the aircraft on a base simultaneously would be an example of _____.
2. Requests to FAA for special flight clearance would be an example of _____.
3. Increased activity at gunnery or bombing ranges would indicate _____.
4. Reports to Civil Engineering, Security Police, Accounting and Finance, and Supply concerning an upcoming operation, would fall into the category of _____.

Procedural Indicators

- a. Public information releases
- b. Posting of operational plan information in unsecure areas.
- c. Posting of rosters, transportation schedules, and dining hall schedules in unsecure areas.
- d. Distinctive emblems or paint on vehicles, buildings or aircraft.
- e. Markings on supplies which could reveal the location or starting date of the operations, such as, nicknames, delivery deadlines, etc.
- f. Logistics build-up or positioning of support materials and facilities.
- g. Special briefings, meetings or religious services.
- h. The use of nicknames; particularly hazardous since they provide an easily recognizable flag for identification of an operation.
- i. Exercising or testing portions of a plan.

In the following exercise, place the letter of the procedural indicator which identifies the violation in the blank space provided, if applicable.

- ____ 5. Unsecure phone conversations about takeoff schedules.
- ____ 6. Duty rosters on squadron bulletin boards.
- ____ 7. T.V. coverage of maneuvers.
- ____ 8. Stockpiling of supplies in exposed areas.
- ____ 9. Sudden appearance of special clothing items or other equipment.

- ___ 10. Identifying codes or nicknames appearing regularly on correspondence, in communications on supplies and equipment or aircraft.
- ___ 11. Personnel restrictions.
- ___ 12. More than normal amount of overtime work.

Communications Indicators

- a. Plain language communications associated with a planned operation and conducted during the planning, preparatory and execution phases.
- b. Use of unchanging or infrequently changing call signs and/or radio frequencies.
- c. Stereotyped message characteristics which are indicative of particular types of military activity.
- d. A significant increase or decrease in message traffic volume.
- e. Activities of new communications facilities in support of an operations plan.

In the following exercise, place the letter of the communication indicator which identifies the communications indicator, in the blank space provided:

- ___ 13. Mobile communications and control facilities moved into position prior to the start of an operation.
- ___ 14. Increased courier flight into and out of a base.
- ___ 15. Unsecured phone conversations concerning an upcoming operation.
- ___ 16. Changing long used call signs just prior to the start of an operation.

You will now take an exercise dealing with the information from this study/workbook.

EXERCISE

1. Servicing all mobile communications equipment on your base would be an example of _____
2. Requesting special spare parts from base supply is an example of _____
3. Posting missile support duty standby rosters on squadron bulletin boards would be what type of procedural indicator?

4. Calling your girl/boy friend to tell them you are breaking your date because of a special project underway is an example of what type communications indicator?

5. Moving all mobile communications equipment to a central location prior to an operation would be what type of vulnerability indicator?

6. Servicing an air conditioner in a Major Command Headquarters building is a/an _____ indicator.
7. Servicing air conditioning equipment in a Major Communications Center would be a/an _____ indicator.

INTELLIGENCE INDICATORS:

- A. Operational
- B. Procedural
- C. Communicational

STOP!

You have completed the direct study assignment in preparation for Day 51.

J3ABR54530 001-VI-1 thru VI-4
and VI-6

Technical Training

Refrigeration and Cryogenics Specialist

COMMERCIAL AIR CONDITIONING

January 1983



3700 TECHNICAL TRAINING WING
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

DESIGNED FOR ATC COURSE USE

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Part 1

Given a disordered list of steps required to replace air handler bearings, shafts, belts and pulleys; and adjustment of damper linkage, place the steps in order with no more than four errors.

In the space provided, list the steps required to replace air handler bearings, shafts, belts and pulleys, and adjustment of damper linkage.

Install bearings	1.	_____
Remove shaft	2.	_____
Remove pulley	3.	_____
Install belts	4.	_____
Adjust damper linkage	5.	_____
Install shaft	6.	_____
Install pulley	7.	_____
Remove power	8.	_____
Remove bearings	9.	_____
Remove belts	10.	_____

Given the information, state the steps for lubricating air handler bearings and checking the bearings, belts, and pulley alignment with no more than three errors.

In the space provided, state the steps for lubricating and checking bearings, belts, and pulley alignment.

Bearings	
Belts	

Pulley



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CENTRIFUGAL AIR CONDITIONING

Part 1

OBJECTIVE

Select from a list of principles, those that apply to the operation of centrifugal air conditioning system with no more than two errors.

PROCEDURE

Given the list of principles of operation, underline those that apply to the centrifugal air conditioning system.

1. Must move a large volume of refrigerant to achieve large cooling capacity.
2. Must be in a deep vacuum.
3. Liquid refrigerant flows by gravity from the condenser to the evaporator.
4. Lithium bromide having the ability to absorb large amounts of water vapors.
5. Suction dampers is used as capacity control.
6. Compressor uses two pistons for compression.

Part 2

OBJECTIVE

Given a flow diagram of the refrigerant, chilled water, and condenser water systems, indicate by designated colors and arrows the flow and direction of each system. No more than two errors permitted.

PROCEDURE

- Correctly trace the flow (cycle) of refrigerant through the primary refrigerant system.
- Identify operation and maintenance procedures and trace the flow of liquid through the secondary refrigerant system.
- Identify and explain the functions of major components of the centrifugal refrigeration machine.

Using figure 1 and colored pencils, complete the following:

- a. Color with a light green pencil the condenser water circuit, indicate the water inlet and outlet connections with arrows showing direction of flow.
 - b. With a regular lead pencil, darken the chilled water circuit, and indicate, with arrows, the chilled water inlet and outlet connections.
 - c. With a red pencil, color the high pressure refrigerant gas and liquid.
 - d. With a blue pencil, color the low pressure refrigerant gas and liquid.
 - e. Use arrows to indicate the direction of refrigerant flow.
 - f. Describe in your own words, the flow of refrigerant through the centrifugal machine.
-
-

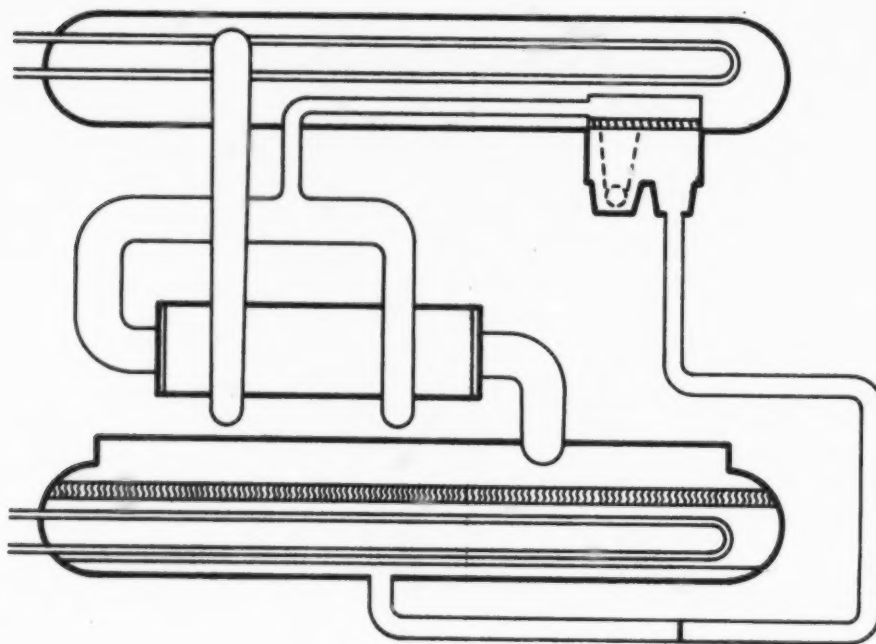


Figure 1. Refrigerant and Water Flow

Using the diagram you have just completed, go to the machine and trace the flow of refrigerant.

Operation, Maintenance and Flow of Secondary Refrigerants

Proceed to the centrifugal unit and trace the condenser and chilled water circuit through the chiller. When you have done this, answer the following questions without error.

1. What liquid circulating unit in the centrifugal system is considered to be a closed circuit?

2. What liquid circulating unit in the centrifugal system is considered to be an open circuit?

3. What is the purpose of the butterfly valve?

4. Where does chilled water enter the evaporator?

5. Why is there a condenser, cooling tower, and water storage tank?

6. At what point in the centrifugal unit's condenser must condenser water enter first?

Why? _____

Identification and Function of Major Components
of the Centrifugal Refrigeration Machine

Locate the following components on the machine and explain their function.

1. Motor

a. Voltage: _____

b. Amperage: _____

c. Function: _____

d. Horsepower: _____

e. Cooling Means: _____

2. Compressor

a. Type: _____

b. Number of Stages: _____

c. Purpose: _____

d. Speed: _____

3. Condenser

a. Purpose: _____

b. Refrigerant Inlet Location: _____

c. Refrigerant Outlet Location: _____

d. Normal Condenser Pressure and Temperature: _____

e. Type of Design: _____

f. Purpose of the Baffle: _____

g. Secondary Purpose: _____

4. Economizer

- a. Purpose: _____

- b. Approximate Pressure: _____
- c. What maintains this pressure?

5. Evaporator

- a. Type: _____
- b. Inlet Location: _____
- c. Outlet Location: _____
- d. Normal Refrigerant Temperature: _____
- e. Refrigerant Level: _____
- f. Purpose of the Baffle: _____

- g. Purpose of the Distributor: _____

- h. Purpose of the Eliminator: _____

6. Capacity Control

- a. Type: _____
- b. Purpose: _____

- c. How is it controlled?

7. Purge Unit

- a. Purpose: _____

- b. Type of Compressor: _____
- c. Safety Devices: _____

Part 3

OBJECTIVE

Given the information, state the steps in maintaining the chilled water system with no more than one error.

PROCEDURE

In the space provided, state the steps in maintaining the chilled water system.

Evaporator tubes: _____

Water treatment: _____

Part 4

OBJECTIVE

Given the information, list the steps required for pressure checking the refrigeration systems with dry nitrogen. No more than two errors permitted.

PROCEDURE

In the space provided, list the steps required for pressure checking the refrigeration systems with dry nitrogen.

Steps

1. _____

2. _____

3. _____

4. _____

5. _____

Part 5

OBJECTIVE

Given a disordered list of steps required for charging a centrifugal system with refrigerant, place the steps in order with no more than two errors.

PROCEDURE

In the space provided, arrange the steps in order required for charging a centrifugal system with refrigerant.

- Accurately check refrigerant level before attempting to add refrigerant. If refrigerant level is low, determine the cause for the loss before proceeding.
- Close charging valve and disconnect refrigerant drum.
- Charge until liquid level appears in center of evaporator sight glass.
- Charge until liquid level appears in center of evaporator sight glass.
- Elevate drum above liquid level in evaporator to induce a gravity flow.

Part 6

OBJECTIVE

Working as a member of a team and using a centrifugal system trainer, check, adjust and perform maintenance on the compressor and system controls with instructor assistance.

EQUIPMENT

Trainer, centrifugal air conditioner system

PROCEDURE

1. Check settings of all controls and safety switches.

NOTE: Make adjustments as necessary upon instructor approval.

- a. Chilled water control 45°.
- b. Condenser water control 85°.
- c. Oil pressure control cut-out 4 psi, cut-in 8 psi usable oil pressure.
- d. Oil temperature control 130-135° differential fixed 5°.
- e. Low temperature control cut-out 32°, cut-in 42°.
- f. Motor temperature control cut-out 120°, cut-in 110°.
- g. High pressure control cut-out 2-inch vacuum, cut-in 12-inch vacuum.
- h. Purge high pressure control cut-out 40 psi, cut-in 25 psi.
- i. Purge heater temperature control cut-out 140°, cut-in 132°.

Part 7

OBJECTIVE

Working as a member of a team and using a centrifugal system trainer, operate the purge recovery unit with instructor assistance.

EQUIPMENT

Trainer, centrifugal system purge unit.

PROCEDURE

- Using the centrifugal unit and figure 2, identify the components and their purposes by the corresponding numbers.
- Operate the purge recovery unit with instructor assistance.

A.

NUMBER	NAME	PURPOSE
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		

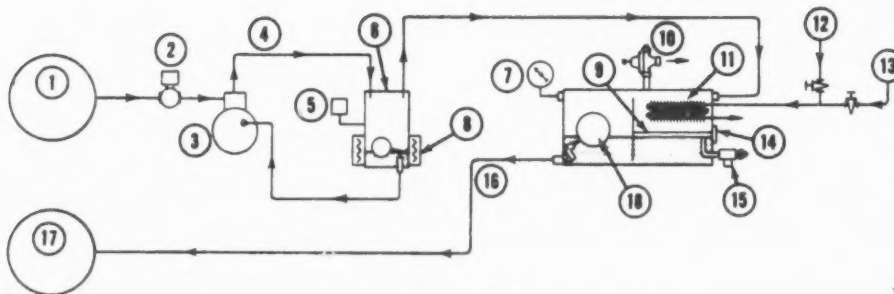


Figure 2. Purge Recovery Unit

15		
16		
17		
18		

B. Answer the following questions.

1. What are the noncondensables that the purge unit must remove from the unit?

2. How is the purified refrigerant returned to the cooler?

3. What causes the refrigerant vapor to condense once it is in the purge drum?

4. How does the purge drum separate the refrigerant, air and water?

5. Why are there two water supply valves going to the purge drum?

6. For what reason is the oil separator maintained between 132° and 140°F?

c. Operate purge recovery unit.

(1) Depress the purge compressor switch to manual (located on the centrifugal control panel).

(2) Observe operation/purge drum sightglass.

(3) Depress the purge compressor switch to the off position.

(4) If required, remove the water thru the manual blow-off valve.

Part 8

OBJECTIVE

Working as a member of a team and using a centrifugal system trainer, operate the compressor and perform the operational checks on the system while applying safety precautions pertaining to high intensity sound with instructor assistance.

EQUIPMENT

Trainer, centrifugal air-conditioning system

PROCEDURE

Perform preoperational check and operation of centrifugal machine to optimum efficiency and performance.

Preoperational Check and Operation of Centrifugal Machine

Preoperational Check

1. Insure all power is off
 - a. Main circuit breaker.
 - b. Secondary breakers.
2. Check oil levels
 - a. Compressor oil sump
 - b. Purge compressor
3. Check evaporator liquid level
 - a. Located below and to the right of the control panel
 - b. 1/2 bulls eye
4. Check supply air pressure gauge located on left side of control panel (20 psi).
5. Check the position of the following switches:
 - a. Unit Control Panel (see figure 3)
 - (1) S-1 Compressor oil pump - AUTO
 - (2) S-2 Purge oil heater - ON
 - (3) S-3 Purge compressor - AUTO
 - (4) S-4 Manual demand limiter - 40 PERCENT
 - (5) S-5 Reset - RESET
 - b. Main Power Panel
 - (1) S-10 Condenser water pump - ON
 - (2) S-11 Cooling Tower Fan - AUTO

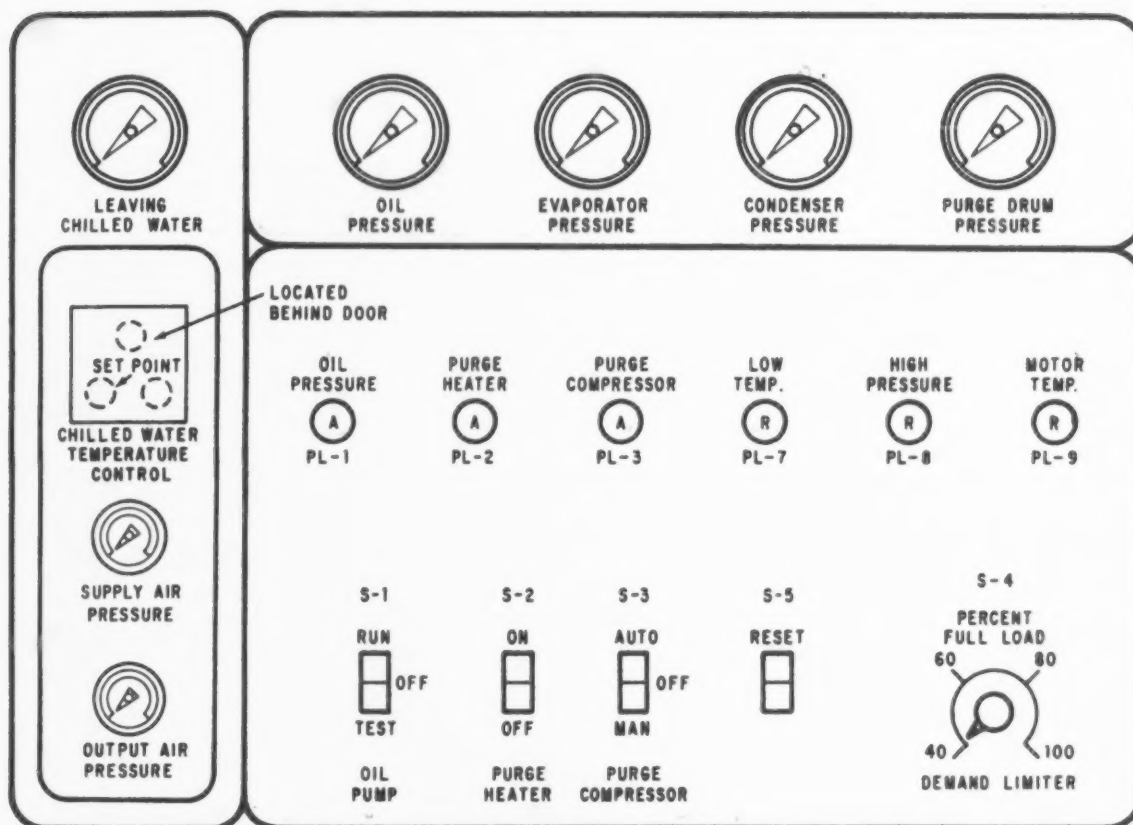


Figure 3. Control Panel

6. Turn on main circuit breaker at this time.

NOTE: Purge oil heater is now energized.

7. Check unit control panel indicator lights.

- a. Red lights for low temperature, high pressure, and motor temperature control should be out.

NOTE: If any red indicator lights are lit, depress reset switch.

- b. Amber lights

(1) Purge heat - lit

(2) Oil pressure, purge compressor off

8. Turn five circuit breakers, located next to main breaker, ON.

9. Turn on all circuit breakers, located in circuit breaker panel directly above centrifugal electrical panel, ON.

10. Depress start buttons for both single and multi-zone air handlers.

NOTE: Air handlers are now operating.

Unit Start Up

NOTE: Prior to start up, insure all steps have been completed on preoperational check. Check indicator lights on unit control panel. Only one light should be illuminated, the amber light for the purge heater.

1. Depress start button PB1, located on Main Power control panel. This will start the chilled water pump, closing its two sets of auxiliary contacts.

2. The following sequence of events will occur automatically.

- a. Condenser water pump starts.

- b. Power is applied to the cooling tower fan thermostat and it will now cycle to maintain temperature.

- c. Power applied to oil pump switch S-1.

- d. Oil pump starts.

- e. Oil pressure control closes, amber light lights.

- f. Compressor starts, starting 30-minute time delay restart cycle.

NOTE: Unit cannot be restarted until time delay times out.

- g. After approximately five seconds, solenoid air valve opens.

NOTE: This allows unit to start with the suction dampers closed. Allows compressor to start and come up to full speed completely unloaded.

- h. Purge compressor starts, amber light lights on control panel. Check purge unit for proper operation.

3. Centrifugal machine is now in full operation under control of TC1 and Load Limiting relay.

NOTE: At this time, check the control panel for indicator lights. Should have three amber lights lit, NO red lights.

Operating Procedures

Let unit operate at 40 percent load for 10 minutes, then make the following recordings:

1. Condenser Inlet Temperature: _____
2. Condenser Outlet Temperature: _____
3. Chilled Water Inlet Temperature: _____
4. Chilled Water Outlet Temperature: _____
5. Oil Pressure: _____
6. Evaporator Pressure: _____
7. Condenser Pressure: _____
8. Purge Drum Pressure: _____
9. Supply Air Pressure: _____
10. Output Air Pressure: _____

NOTE: Items 4 through 10 are located on control panel.

11. Unit Amperage Draw, as indicated on ammeter: _____
12. Your instructor will determine if the load is sufficient to increase the manual demand limiter switch above 40 percent. If it is, take the previous readings for increased setting after unit has stabilized.

1. Centrifugal Machine Operational Control

- a. List the control that operates the centrifugal machine.

- b. List the control which regulates the cooling capacity.

- c. How does the demand limiting mechanism function?

2. Chilled Water System Control

- a. How is chilled water controlled at the individual cooling coils?

- b. The chilled water is modulated to control what variable?

- c. How does the amount of chilled water flow affect the operation of the centrifugal machine?

Stopping Procedures

1. Depress stop button TB1, located on Main Power Control Panel.
2. Turn the following switches to the indicated position.

a. Control Panel:

- (1) Oil Pump - OFF
- (2) Purge Heater - ON
- (3) Purge Compressor - OFF
- (4) Reset - RESET
- (5) Demand Limiter - 40 PERCENT

b. Main Power Panel:

- (1) Condenser Water Pump - OFF
- (2) Cooling Tower Fan - OFF

3. Turn OFF all remaining circuit breakers, one at a time.
4. Turn OFF master breaker.
5. What is the function of the load limiting mechanism?

6. How does this unit affect the operation of the centrifugal machine?

7. Can this unit be run without the purge unit? Explain your answer.

ABSORPTION AIR CONDITIONING

OBJECTIVE

Using an absorption system trainer and an absorption cycle schematic, label the major components and trace the flow of the solution and refrigerant. No more than 4 errors permitted.

EQUIPMENT

Trainer, air conditioner, absorption

PROCEDURE

- Identify the lettered components in figure 4 and write their names after the corresponding letters in the space provided.
- Locate and trace the flow of refrigerant and absorbent in a lithium bromide system, using a lithium bromide flow chart and an absorption system trainer.

1. A _____

B _____

C _____

D _____

E _____

F _____

G _____

H _____

I _____

J _____

K _____

L _____

M _____

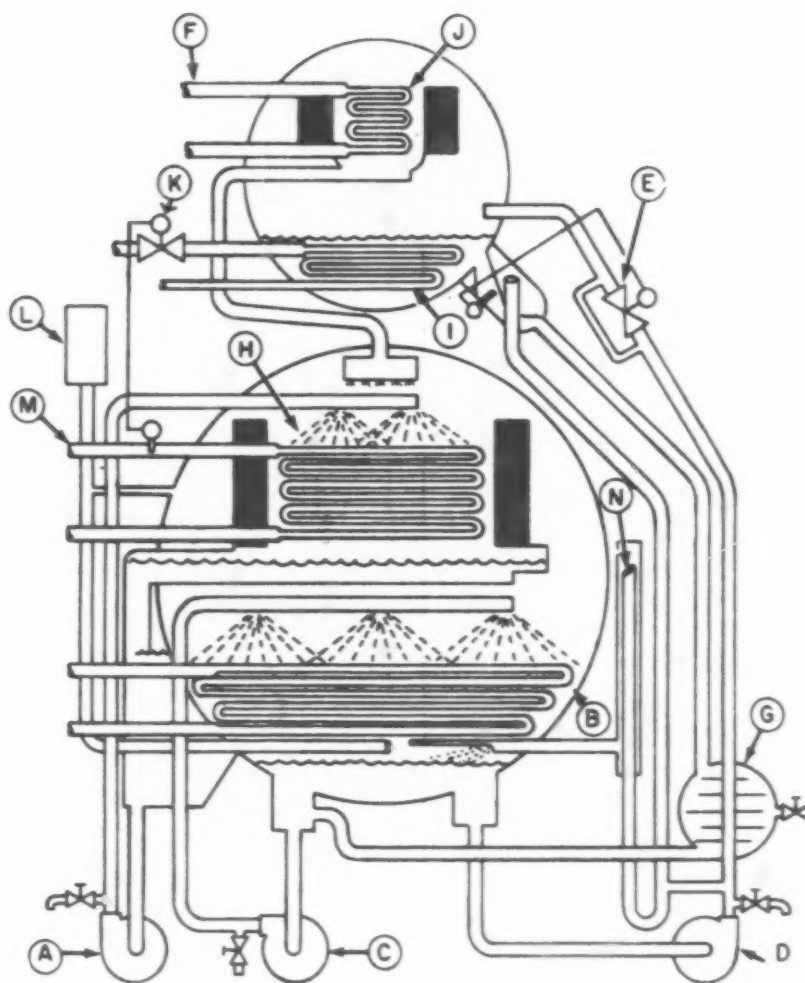


Figure 4. Lithium Bromide Absorption System

2. Refrigerant and Absorbent Flow

1. Obtain a red and blue pencil from your instructor.
2. Refer to figure 4.
3. Color in the flow of weak solution from the bottom of the absorber to the generator using light red. Draw an arrow to show direction of flow.
4. Color in the flow of strong solution from generator to absorber spray nozzles using heavy, dark red coloring. Draw an arrow to show direction of flow.
5. Color in primary refrigerant flow from condenser to evaporator using heavy dark blue coloring. Draw an arrow to show direction of flow.
6. Color in cooling tower water using light blue coloring. Draw arrow showing direction of flow.
7. Color in chill water flow using a regular pencil. Label the chill water line "Chill Water."
8. Locate the steam line and label it "Steam Line."
9. Using the diagram you have just completed, go the machine and trace the flow of refrigerant and solution.

Part 2

OBJECTIVE

Given the information, state the procedures for leak testing the absorption air conditioning system, with no more than 3 errors.

PROCEDURE

In the space provided, list the procedures for leak testing the absorption air conditioning system.

1. Vacuum Test

2. Pressure Test

Part 3

OBJECTIVE

Using an absorption system trainer and equipment provided, operate the system. While operating the system, record temperature and pressure readings on the system operation. No more than 2 errors permitted.

EQUIPMENT

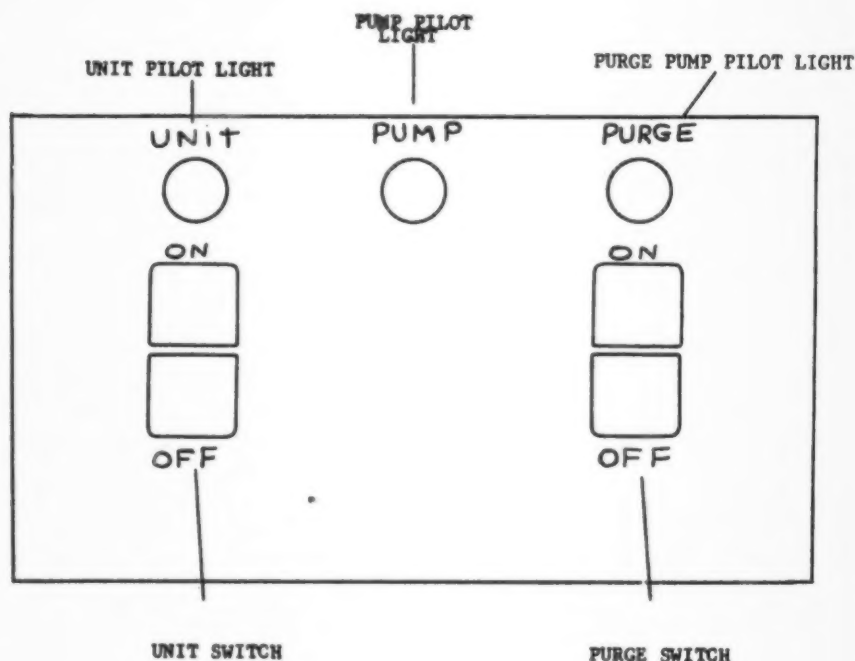
Trainer, air conditioner, absorption, mercury thermometers

PROCEDURE

Perform preoperational checks, start-up and shut-down procedures as outlined in the workbook project when your instructor so indicates.

1. Insure the machine switch (S-2) is in the off position.
2. Insure all power is on (motor control panel).
 - a. Main breaker
 - b. Absorption unit
 - c. Air handler
 - d. Chilled water pump
 - e. Condenser water pump
 - f. Cooling tower fan
3. Perform a standing vacuum test.
4. Check purge compressor oil level and condition of the oil.
 - a. Oil level - Between the two marks on the oil level sight glass.
 - b. Oil must be cleared.
5. Operate purge recovery unit
 - a. Turn switch (S-1) on.
 - b. Open the manual shutoff valve.
6. Make certain the pneumatic control system is under 20 psig main air pressure.
 - a. Main air gage is located on the absorption unit.
 - b. Make certain the refrigerated air dryer located in the centrifugal classroom is on.

7. Make certain there is hot water under pressure going to the concentrator.
 - a. Hot water temperature - approximately 180°F.
 - b. Turn on the hot water converter and select absorption machine with the electrical switch located in centrifugal classroom.
8. Check switches in the pneumatic control panel.
 - a. Pre-heat coil - manual.
 - b. Cooling water - manual.
 - c. Heat exchanger for condenser water manual.
 - d. Heat exchanger load - manual.
9. Open access valves "A" and "B," valves "C" and "D" closed (pump motor cooling and lubrication connections).
10. Visually inspect the unit and air handler for defects and water leakage.



Electric Control Panel

Unit Start Up

CAUTION: Prior to start up, insure all steps have been completed on preoperational check. Do not start the unit until the instructor says to do so.

Motor Control Panel

1. Press start, chilled water pump. (DS-2)
2. Auto, condenser water pump. (DS-3)
3. Auto, cooling tower fan. (DS-4)
4. Press start, air handler. (DS-5)
5. Depress S-2 to the on position.

NOTE: The unit will start at this time; however, if the unit shuts down within 30 seconds to 2 minutes in operation, the unit may have cycled off on a safety. The instructor will explain the procedures for resolving the malfunction and restarting the unit.

OPERATING PROCEDURES

Let the unit operate for 15 minutes, then make the following recordings:

Thirty Minute Intervals

1. Strong sol lvg conc		
2. Strong sol lvg HX		
3. Intermediate sol abs spay		
4. Dilute sol lvg abs		
5. Dilute sol lvg HX		
6. Refrigerant		
7. Chilled H ₂ O in		
8. Chilled H ₂ O out		
9. Cooling H ₂ O in abs		
10. Cooling H ₂ O out abs		
11. Cooling H ₂ O out ods		
12. Solution level		
13. Refrig level - spill		
14. Hot H ₂ O in		
15. Hot H ₂ O out		

Remarks & Comments:

Stopping Procedures

1. Depress S-2 to the off position on the absorption control electric panel and allow the machine to complete its dilution cycle.
2. After dilution cycle timer has stopped the machine, position the following switches, located on the motor control panel.
 - a. Press stop, chilled water pump. (DS-2)
 - b. Off, condenser water pump. (DS-3)
 - c. Off, cooling tower fan. (DS-4)
 - d. Press stop, air handler. (DS-5)
3. Turn off the following circuit breakers, located on the motor control panel.
 - a. Air handler
 - b. Chilled water pump.
 - c. Condenser water pump.
 - d. Cooling tower fan.

CAUTION: Do not turn off the main breaker and absorption unit breaker.
4. Depress the S-1 to the off position (purge unit), and close the manual shutoff valve.
5. Turn off the hot water converter and select the centrifugal machine with the electrical switch in the centrifugal classroom.

CYLINDER UNLOADERS AND HUMIDITY CONTROL

Part 1

OBJECTIVE

Given a list of ten statements, select three of the five which describe the operating principle of cylinder unloaders.

PROCEDURE

Select three of the five statements which describe the operating principle of cylinder unloaders.

- ___ 1. Cylinder unloaders are used universally on large centrifugal compressors.
- ___ 2. Capacity control is maintained by holding the suction valves open.
- ___ 3. Cylinder unloading may be accomplished electrically, pneumatically or hydraulically.
- ___ 4. When the unit starts, there are two cylinders operating.
- ___ 5. The ideal setting of the capacity control valve is achieved when the first cylinder unloads at a pressure of 5 psi below the design suction pressure.
- ___ 6. Cylinder unloaders use the internal oil pressure to operate.
- ___ 7. When the unit shuts down, there is only one cylinder operating.
- ___ 8. Cylinder unloaders load the cylinders as the heat load decreases.
- ___ 9. A system using cylinder unloaders will maintain a very close temperature control.
- ___ 10. Turning the adjusting stem clockwise (in) loads the cylinders.

Part 2

OBJECTIVE

Working as a member of a team and using an air conditioner trainer, adjust the cylinder unloaders to value specified by the instructor with instructor assistance.

EQUIPMENT

Trainer, Air Conditioner
Amprobe

PROCEDURE

Using an air conditioner trainer, operate and adjust the cylinder's unloaders as outlined.

Adjustment Procedure

1. Determine a pressure that is equal to a 40°F coil temperature using a PT chart.
2. Turn the adjusting stem counterclockwise to load all cylinders.
3. Throttle the suction service valve until the desired pressure is achieved at the suction gage.
4. Turn the adjusting stem clockwise to unload one cylinder.

Part 3

OBJECTIVE

Given a list containing ten statements relative to the types and purpose of humidity control equipment which are correctly stated.

- ___ 1. The high limit humidistat (H-1) will override the thermostat and command the face damper to open more than 1/2.
- ___ 2. The humidistat has control of the reheat coil.
- ___ 3. Relative humidity control usually allows a greater tolerance but must be low enough to minimize rust and corrosion while high enough to prevent static electricity charges from arcing.
- ___ 4. The DX coil, having a mean surface temperature (apparatus dew point) of about 45°F will remove more grains of moisture from the circulating air and in time will lower the space relative humidity.
- ___ 5. H-1 is wired in series with T-1.
- ___ 6. The low limit humidistat control the reheat coil.
- ___ 7. The low limit valve has a failsafe motor.
- ___ 8. Low limit humidity is controlled by another humidistat (H-2), which can control either a modulating steam valve or spray nozzles to add moisture to the conditioned space.
- ___ 9. The air flow switch is wired parallel with H-2 circuit.
- ___ 10. The purpose of the air flow switch is to shut down the system when there is no air flow.

Part 4

OBJECTIVE

Given the information, state the adjustment procedure for humidity control equipment with no more than one error.

PROCEDURE

In the space provided, state the adjustment procedure for humidity control equipment.

PUBLICATIONS

Part 1

OBJECT

Select from a list of five definitions the one which defines the scope and application of the technical order system.

PROCEDURE

From a list of five definitions, underline the one which defines the scope and application of technical order system.

1. General in content and not issued against specific systems or equipment.
2. Instructions for modifying equipment and performing one time inspections.
3. Provides technical information, instruction, and safety procedures pertaining to the operation, installation, maintenance, inspection and modification of all Air Force materials and equipment of a highly technical nature. Applied to all Air Force and civilian DOD personnel.
4. A lawful order.
5. Explains the TO system.

Part 2

OBJECTIVE

Use the manufacturer's manual, perform one of the following maintenance tasks as designated by the instructor.

1. Check purge pump and motor pulley alignment.
2. Check V-belt tension.